Domesticating low and zero carbon energy technology in new homes: pivotal events, determining configurations and influential feedback

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Submitted for the degree of PhD

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2014

Declaration of authorship

I, Lise Andreassen, hereby declare that this thesis and the work presented in it is entirely my own. Where I have consulted the work of others, this is always clearly stated.

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Abstract

Recent and forthcoming amendments to the Building Regulations in England and Wales will necessitate an increasing reliance on low and zero carbon (LZC) energy technologies in new homes to meet tougher carbon dioxide (CO_2) emission standards; this will impact on those that design, build, regulate and live in new homes. Given the shifts in domestic energy technology configurations that will be encountered, it is prudent to consider how interactions between householders and LZC technology develop, as this will influence the success of this shift in terms of CO_2 reductions achieved. This is the objective of this thesis.

An early test-bed for the accelerated introduction of LZC technology into new homes is provided by certain local authorities that have adopted innovative planning policies. One such local authority was selected as the study area for this research, in which a borough-wide survey of new home occupants was undertaken, followed by semi-structured householder interviews.

Using methodological and theoretical perspectives from science and technology studies, the research finds that LZC technology-householder associations are influenced by a myriad of factors (including structural, technological, experiential, social and institutional ones) and that their development should be viewed as an on-going process open to influence and change. The thesis concludes that the range of interactions observed between householders and their LZC technologies, together with the high prevalence of faulty installations, signifies that the change envisaged and driven by local policy-makers (in terms of projected CO_2 reductions) is only partially underway. More specifically, the thesis's original contributions include advances in current knowledge relating to, firstly, how householders engage with feedback associated with LZC technology; secondly, the extent of interactions between LZC technology-users within developments; thirdly, the extent of maintenance and repair processes and how these shape householders and technology; and, fourthly, the gendered nature of LZC technology-householder associations.

Acknowledgements

This research was supported by the Royal Geographical Society (with the Institute of British Geographers) with a Postgraduate Research Award, for which I am very grateful.

I would like, firstly, to thank Klaus Dodds, Mike Dalton and Alex Loftus, whose blend of academic interests, styles and valuable feedback have provided a very supportive and trusting supervisory team.

The research is based on contributions from numerous research participants and I am mindful and appreciative of the time and effort that they spent in completing the survey questionnaire and in participating in the interview process. I am also grateful to various employees at Woking Borough Council who enthusiastically engaged with this research and its findings.

My family has been very supportive of my preoccupation with this research over the last four years. Most of all, I would like to thank Simon for his understanding, interest, encouragement and proof-reading.

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Abbreviations

ANT Actor-network theory

ASHP Air source heat pump

CCC Committee on Climate Change

CHP Combined heat and power

CSH Code for Sustainable Homes

CO_2 Carbon dioxide

CO_2e Carbon dioxide equivalent

DCLG Department for Communities and Local Government

DECC Department of Energy and Climate Change

Defra	Department for Environment, Food and Rural Affairs
EPBD	Energy Performance of Buildings Directive
EST	Energy Saving Trust
FIT	Feed-in Tariff
FMA	Framework of linked ideas – Methodology – Area of concern
GSHP	Ground source heat pump
ICT	Information and communication technology
IPCC	Intergovernmental Panel on Climate Change
kWh	Kilowatt hour (unit of energy)
LZC	Low and zero carbon
MCS	Microgeneration Certification Scheme
MVHR	Mechanical ventilation with heat recovery
OECD	Organisation for Economic Co-operation and Development
ONS	Office for National Statistics
PAR	Participatory action research
POE	Post-occupancy evaluation
POST	Parliamentary Office of Science and Technology
PV	Photovoltaics
ppm	Parts per million (measurement of concentration)
RHI	Renewable Heat Incentive
RHPP	Renewable Heat Premium Payment
SAE	Stamped addressed envelope
SAP	Standard Assessment Procedure
STHW	Solar thermal hot water
STS	Science and technology studies
UNFCCC	United Nations Framework Convention on Climate Change
WBC	Woking Borough Council

Chapter 1: Introduction

1.1 Why undertake this research?

In this thesis, I examine how and why householders in new homes come to engage with pre-installed low and zero carbon (LZC) technology[1] as they do. I attend to how the technology is operated, maintained, repaired, regarded and talked about, and how the technology's presence influences householders' daily routines. Why then is this research of relevance? A major reason to study these technology-householder associations is that their prevalence is set to rise (Planning and Climate Change Coalition, 2012) as developers strive to meet increasingly stringent building legislation in England and Wales (UK Government, 2012). This legislative change aims to reduce CO_2 emissions associated with household energy consumption, constituting one of many measures being taken to reduce greenhouse gas emissions linked to climate change (IPCC, 2007).

The accelerated uptake of LZC technology, leading up to 2016 and beyond, will impact on those that design, build, regulate and live in new homes. Although I focus on the latter, these occupants' experiences will be influenced by those that design and build new dwellings, and by those that regulate this process. Whether LZC technology-householder associations deliver the envisaged CO_2 emission reductions will depend to varying degrees (dependent on technology type) on how the technology comes to be installed, used and maintained, and this research advances current knowledge on this.

Published research on LZC technology-householder associations is based mainly on retrofitted installations, or on new developments built to high environmental and/or nearly zero-energy standards (see Chapter 3). Such new housing is unrepresentative of mainstream new housing fitted with LZC technology. Absent from the research literature are studies founded on mainstream new housing spread throughout the geographical area of a local authority in the UK context, and one in which most new developments over recent years have already had LZC technology installed (to meet local planning policy). I have selected to research such an area as it constitutes an early test-bed for the accelerated introduction of LZC technology.

Undertaking borough-wide research has generated insights into the breadth of issues that emanate from incorporating a range of LZC technology into various dwelling types with different tenure arrangements and household compositions. As I make evident through this

[1] Defined in Table 2.1

research, LZC technology-householder associations are influenced by a myriad of (structural, technological, experiential, social and institutional) factors and their development should be viewed as an on-going process open to influence and change. The research finds there are many shaping determinants for these associations, such as technological placements, faulty installations, processes of repair, interactions with feedback, degrees of understanding and conversations. One conclusion drawn is that the change envisaged and driven by policy-makers is only partially underway and the potential quantity of lower carbon energy that these technologies could be delivering (if the quality of the installation was faultless and the technology was optimally operated and maintained) has yet to be realised in many cases.

1.2 A summary of research aims

Through the literature review in Chapters 3 and 4, I derive a set of research questions to address which will advance understandings of LZC technology-householder associations. These research questions, detailed in Section 4.4, are summarised below:

- To what degree is LZC technology actively appropriated as part of the sales/renting process and what are householders' perceptions of the advice imparted on the technology when moving in?
- How are users shaped by the technology's placement, settings and feedback?
- What is the prevalence and impact of faulty installations and maintenance processes?
- How do householders regard LZC technology and does it slot into existing gendered patterns of everyday life?
- To what extent do neighbours provide LZC technology-related support to each other and what role do Residents' Associations play in facilitating information exchange?
- What trials (experiences, interactions or receipt of new knowledge) trigger householders to shift and re-stabilise their socio-technical relations as part of the on-going domestication of LZC technology?

1.3 Structure of the thesis

This thesis is comprised of ten chapters. Following this introduction, Chapter 2 links the research agenda to current efforts being undertaken to reduce greenhouse gas emissions. In progressing from the international to the household scale, global climate change concerns are linked to the specific measure of introducing LZC technology. I provide an account of why LZC technology is set to become commonplace in new dwellings in the UK and thereby justify the rationale for researching associations between householders and such technology. Chapter 2 also explains why certain local authority areas provide a useful test-bed for studying outcomes from the widespread introduction of LZC technology.

Having set the rationale for undertaking research in this field, I proceed in Chapter 3 to review the theoretical and empirical academic research (and grey literature) which contributes to current understandings of how householders come to use, regard, interact with and be influenced by LZC technology. I identify various knowledge-gaps that have informed the formulation of pertinent research questions. In addition to contributing to the extant literature, gaining further insights into how and why householders interact with LZC technology provides opportunities for policy-makers, developers and designers to appraise how they might intervene to improve the design, installation and use of these technologies to deliver enhanced CO_2 reductions.

In Chapter 4, I discuss the theoretical and methodological sources that have guided the research. Studying the ways in which technologies are used and their influence on users requires a consideration of relations that span across the social and technical realms. A socio-technical approach well-suited to such considerations is the technology studies version of domestication theory (Sørensen, 2006). This approach, which guided the research, incorporates aspects of actor-network theory (ANT) (Latour, 2005) into domestication theory (Sørensen, 2006; Silverstone, 2006). The final phase of fieldwork was to involve an action research mode of inquiry which sought to facilitate a desired change to the situation under study. The chapter contributes to the derivation of the research questions guiding this study, and these are summarised at the end of the chapter.

In Chapter 5, I describe and justify the research strategy adopted, the three constituent phases of fieldwork, and the research methods used. The *planned* research phases comprised, sequentially, a borough-wide survey for new home occupants, semi-structured householder interviews and the creation of a householder support network (the intended action research component). I detail how the collated research data was analysed and I finish the chapter with a description of the research participants and their LZC technologies.

In the next four chapters, I present and discuss the research findings, addressing the various research questions. In Chapter 6, I describe and appraise aspects of the embryonic technology-householder association, encompassing the degree to which LZC technology is actively appropriated by householders; the level of documentation and verbal instructions provided by housing industry representatives; and the level of knowledge imparted by departing residents to newcomers. I proceed in Chapter 7 to describe and appraise how householders come to use, regard and interact with their technology and to identify key determinants responsible for the progressive shaping of LZC technology-householder associations. I pay particular attention to how householders are influenced by the technology's placement and settings, and how feedback from the technology engages householders and shapes perceptions and actions.

Chapter 8 describes the extent to which LZC technology is maintained and repaired and establishes reasons for this. I also consider the ways in which householders and technologies are shaped by repair and maintenance processes. In Chapter 9, I explore the extent to which LZC technology is discussed and how it is viewed, focusing on technology-related discussions within homes, within developments and beyond, and the meanings householders ascribe to their technology.

Finally, in Chapter 10, I draw together the research findings and generate a more integrated account of the domestication processes at play between householders and LZC technologies from a socio-technical perspective. I establish the significance of the research by highlighting how it advances current knowledge through generating (1) an improved appreciation of the degree to which LZC-technology is actively appropriated by households during the sales/renting process; (2) a deeper understanding of how the (in)actions of housing industry representatives may not facilitate, and may actively hinder, the development of effective LZC technology-householder associations; (3) an insight into the extent of technology-related information-transfer between successive occupants; (4) a broader understanding (covering several technology types) of how the ways in which LZC technology is physically embedded in the home influences the extent and nature of householders' interactions with it; (5) a substantive contribution in describing the gendered nature of LZC technology-householder associations; (6) a more nuanced understanding of the ways in which the processes of maintenance and repair shape both householders and LZC technology; (7) a more analytical evaluation of householders' engagement with sensory and formal forms of feedback associated with LZC technology; and (8) a substantive contribution in, firstly, describing the extent and nature of interactions between LZC technology-users within developments and, secondly, identifying the degree of involvement of Residents' Associations and Management Committees in LZC technology-related matters. I reflect upon the main research findings in order to examine their consequences.

I also detail in this last chapter how recommendations from the research came to be adopted by the local authority and I explore the factors that may have enabled this to occur. I conclude with suggestions for future research in this field.

Chapter 2: Setting the context and rationale for the research

2.1 Introduction

In this chapter, I explain why LZC technologies are set to become commonplace in new homes in the UK and why, therefore, researching associations between householders and such technology is of relevance. The main driving force behind the incorporation of LZC technology, via planning policy and legal instruments, is human-induced climate change (Eadson, 2012). The technology is also perceived as providing a degree of protection against fuel poverty (EST, 2011a) and energy insecurities, caused by disruptions to energy supplies, unnecessary price fluctuations and over-dependence on geopolitically sensitive sources[2] (DECC, 2009b; DECC, 2011b; Pyrko & Darby, 2011).

In progressing from the international to the household scale, the chapter provides linkages between global concerns on climate change; national targets to reduce greenhouse gas emissions; the housing sector's contribution to such emissions; and the specific measure of introducing LZC technology, underlining the 'complex governance processes required to translate global commitments into national and local actions' (Bailey, 2008, p. 421). The last section explains why certain UK local authority areas provide a useful test-bed for studying the outcomes associated with equipping new homes with LZC technology.

2.2 International & national targets

2.2.1 Climate change concerns

Human-induced climate change is linked to the underlying enhancement of the greenhouse effect through human activities. This effect arises from the absorption of thermal infra-red radiation by specific gases, termed greenhouse gases. This radiation is emitted from the Earth's surface, atmosphere and clouds (arising from the re-radiation of incoming solar radiation) and its absorption is correlated with an increased temperature within the lower atmosphere (IPCC, 2013a). As greenhouse gas concentrations have risen due to human activities (a pre-industrial (1750) global CO_2 concentration of 278ppm rose to 391ppm by 2011 (IPCC, 2013b)), the global mean surface temperature has also risen (by 0.85^0C between 1880 and 2012 (IPCC, 2013b)). With projected increases in greenhouse gas emissions, surface

[2] As discussed more widely by human geographers such as Bradshaw (2010).

temperatures are predicted to increase further to varying degrees, dependent on the scenarios modelled (IPCC, 2013b). The future impacts of global warming are uncertain and differ across the Earth. In the UK, there has already been a rise in sea level (DECC, 2013b), an earlier beginning to spring (DECC, 2013c), a 1^{O}C higher annual mean surface temperature (DECC, 2013d) and observable impacts on ecosystems (Defra, 2007).

Perceptions of human-induced climate change have progressed from a possible, to a probable and on to a scientifically endorsed footing over the last 50 years. In the 1970s, climatologists observed that the Earth's surface temperature was rising and that this tied in with increasing atmospheric CO_2 concentrations. To better understand this, the United Nations Environment Programme and World Meteorological Organisation established the Intergovernmental Panel on Climate Change (IPCC) in 1988. The IPCC has since issued five assessment reports on the state of scientific knowledge to guide policy-makers' efforts to address climate change (IPCC, 2013c). In its fifth report, the IPCC states it is '*extremely likely*[3] that human influence has been the dominant cause of the observed warming' (IPCC, 2013b, p. 17).[4]

2.2.2 International & national targets to reduce greenhouse gas emissions

One major effort to address climate change was launched at the Rio Earth Summit in 1992 with the adoption of the United Nations Framework Convention on Climate Change (UNFCCC), which aims to stabilise greenhouse gas concentrations 'at a level that would prevent dangerous anthropogenic interference with the climate system' (UNFCCC, 1992, p. 9).[5] The Kyoto Protocol was created to drive efforts to meet this objective, specifying individual mandatory greenhouse gas emission targets for the European Union (EU) and 37 other developed countries (UNFCCC, 1998). The 2008-2012 EU target required that average emissions be 8% less than in 1990 (UNFCCC, 1998), with the UK-assigned reduction target being 12.5%. A 2013 compliance update established the UK had achieved a 26.7% reduction by 2012 (DECC, 2013e). In December 2012, with the time frame for the first commitment under the Protocol ending, an amendment was adopted wherein the EU offered to work towards a 30% reduction in emissions by 2020 (based on 1990 baseline emissions), on the condition that 'other developed countries commit themselves to comparable emission reductions and

[3] 95-100% probability (IPCC, 2013b)

[4] In 2008, 20% of a surveyed sample of the UK public still considered climate change unrelated to human activities (Whitmarsh, 2011), and a higher proportion were uncertain about this.

[5] Bulkeley & Newell (2010, p.28) note that 'defining what counts as "dangerous" is a political act, a judgement about risk'.

developing countries contribute adequately according to their responsibilities and respective capabilities' (UNFCCC, 2012, p. 3).

Alongside these international initiatives[6], the UK Government is legally bound to various European Directives. Of particular relevance to LZC technology in new developments are the Energy Performance of Buildings Directive (EPBD) (European Parliament, 2010b) and the Renewable Energy Directive (European Parliament, 2009). The latter requires renewable energy technology to increasingly contribute to meeting UK energy demands, rising from a 1.3% contribution in 2005 to 15% by 2020. Within the residential sector, LZC technology is predicted to meet 4% of energy demand by 2020 (DECC, 2010a).

The EPBD is the main EU legal instrument designed to lower energy consumption from new buildings (European Parliament, 2010b; Ekins & Lees, 2008), requiring them to be 'nearly zero-energy' by 2020 (Article 9) through achieving high energy performance standards[7]; a building's residual energy demand will need to be provided to a 'very significant extent' by renewable energy sources (Article 9).

These and other directives have necessitated the development of national targets and legislation to help achieve compliance (UK Government, 2012; DECC, 2010a; Lockwood, 2013). The UK was the first to set national, self-imposed reduction targets for greenhouse gas emissions (DECC, 2009a; Owens, 2010)[8] and these are enshrined within the Climate Change Act 2008 (UK Government, 2008; Bulkeley, Hodson, & Marvin, 2012). This requires an 80% reduction in emissions by 2050, using a 1990 or 1995 baseline (dependent on the gas); there are interim targets of 34% by 2020 (UK Government, 2009a) and 50% by 2025 (House of Commons Library, 2011). To meet these targets, a range of measures will need implementing across a multitude of sectors, including housing and energy generation. Bailey et al. (2011, p.685) assert that the imposition of such targets has become 'politically viable' through a combination of factors, including our technological ability to reduce emissions[9], the economic case for reducing emissions sooner rather than later, and the additional benefits that might accrue from measures undertaken.

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[6] As supplemented by a host of transnational governance initiatives (e.g. ICLEI: Cities for Climate Protection) (Bulkeley, Hodson, & Marvin, 2012).

[7] The Energy Efficiency Directive 2012/27/EU also acts as a potential driving force for improvements in building energy-efficiency via a 20% EU reduction target in primary energy consumption by 2020.

[8] As advocated by the Royal Commission on Environmental Pollution (RCEP) in 2000 (Lovell, Bulkeley, & Owens, 2009).

[9] The emphasis on technology-based solutions to tackling climate change is reflective of the 'ecologically modern' approach being followed (Lovell, 2008, p. 623).

To drive and inform progress against these targets, the Climate Change Act 2008 requires that carbon budgets be set and reported against for a series of 5-year periods, commencing with 2008-2012. The first four carbon budgets translate into cumulative greenhouse gas emission reductions of 23%, 29%, 35% and 50% (DECC, 2011a; House of Commons Library, 2011) and the Carbon Plan outlines the envisaged reduction strategies (DECC, 2011a) necessary for the UK to adhere to the pace of transitioning to these lower carbon futures[10]. The impact of implemented measures on emissions is calculated annually (UK Government, 2009b) and with a 24.8% reduction reported in 2012, the first carbon budget has been met (DECC, 2014a).

Measures undertaken to promote compliance with the Renewable Energy Directive target are outlined in the UK Renewable Energy Roadmap (DECC, 2011c), as updated (DECC, 2013g). For England, these measures include the Renewables Obligation and Feed-in Tariffs (FITs) (which address renewable electricity generation), and the Renewable Heat Incentive (RHI) and Renewable Heat Premium Payment (RHPP) (which address renewable heat generation). The Microgeneration Strategy (DECC, 2011b) provides further details on the promotion of household renewable energy, including actions to improve the quality of installations (via the Microgeneration Certification Scheme[11] (MCS) and the raised competence of installers); to improve the accuracy of the predictive modelling used to assess the contribution that these technologies make to energy provision (via amendments to the Standard Assessment Procedure (SAP)); and to promote the durability of relevant technologies (via manufacturer and workmanship warranties, for example). Another significant measure promoting renewable energy generation (mainly at the 'micro' but potentially also at the 'meso' scale (Walker & Cass, 2007, p. 460)) is the series of scheduled amendments to the Building Regulations, which will require 'zero-carbon' homes to be built from 2016 (Greenwood, 2012; Pickvance, 2012; Goodchild & Walshaw, 2011; McLeod, Hopfe, & Rezgui, 2012; DECC, 2013f). The Building Regulations (returned to in Section 2.3) set out the energy performance standards that need to be met by new buildings.[12] Before discussing the zero-carbon homes concept, I provide an outline of the greenhouse gas emissions associated with the residential sector.

[10] See Brown et al. (2012) for a theoretical perspective on transitions.
[11] The MCS is a quality assurance scheme for LZC technology certification (MCS, 2014).
[12] Rydin & Turcu (2014) present an informative review of UK policies pertaining to low-energy buildings over the last 20 years.

2.2.3 UK housing sector emissions

Recent trends

Within the UK, CO_2 accounted for 83% of greenhouse gas emissions in 2011 (DECC, 2013h) and is primarily generated via fossil fuel combustion (coal, natural gas and oil), occurring mainly within the energy supply and transportation sectors (DECC, 2013h). The residential sector constitutes a major consumer of fossil-fuel derived energy and accounted for 29% of UK CO_2 emissions (and 25% of greenhouse gas emissions) in 2012 (DECC, 2014b), based only on day-to-day household activities (excluding emissions associated with construction activities, for example).

In absolute terms, greenhouse gas emissions from the residential sector declined 14% between 1990 and 2012 but, over the same period, its *relative* contribution to total emissions rose from 22% to 25% (DECC, 2014b); this significant contribution highlights why tackling household energy consumption is key to meeting greenhouse gas emission reduction targets (DCLG, 2011; DECC, 2011b; DECC, 2013i). Much of such consumption delivers space heating (60% in 2011 (DECC, 2012a)) (Figure 2.1). As illustrated in Figure 2.2, energy consumption for water heating has steadily decreased; energy consumption for space heating has shown high variability; and energy consumed by lighting and appliances has steadily increased, driven mainly by home computing and consumer electronics (DECC, 2012d).

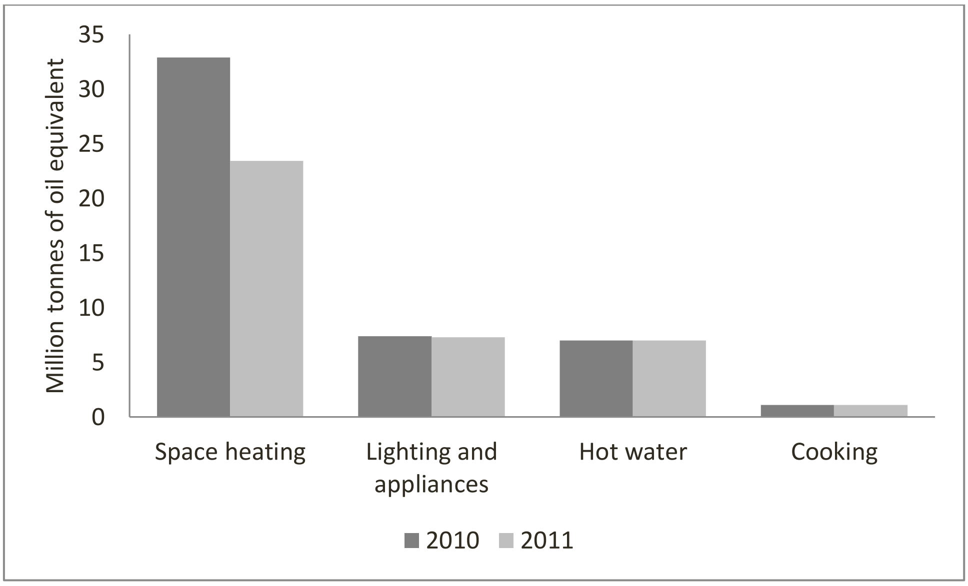

Figure 2.1 Domestic energy consumption by end-use in 2010 and 2011 (Source: DECC, 2012d)

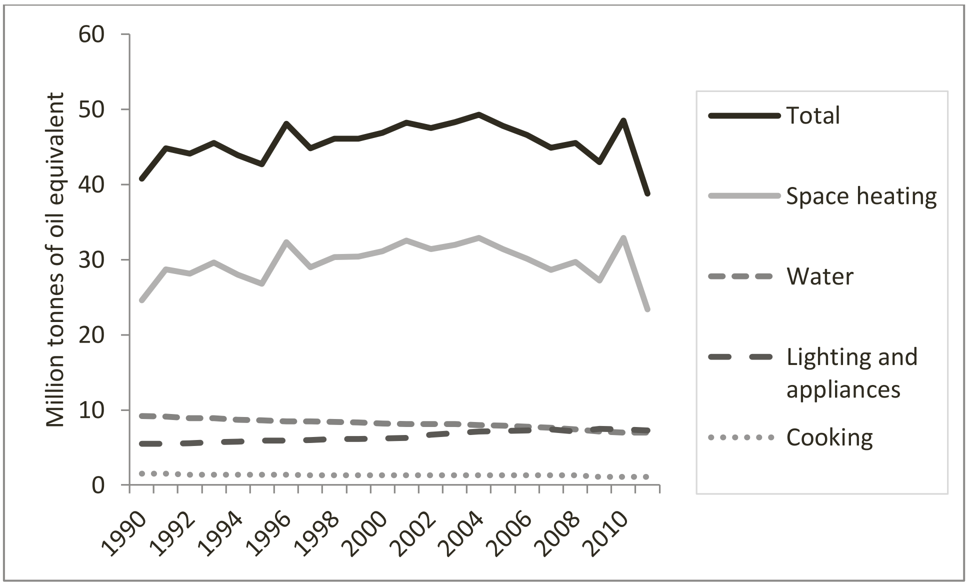

Figure 2.2 Trends in domestic energy consumption by end-use (1990-2011) (Source: DECC, 2012d)

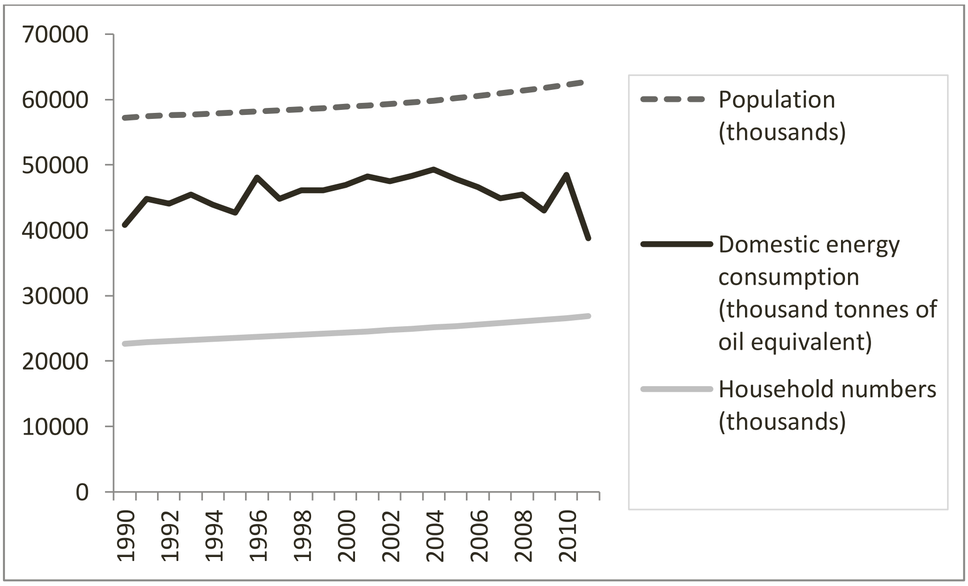

Figure 2.3. Trends in population size, household numbers and domestic energy usage (1990-2011) (Source: DECC, 2012d)

The residential sector's emission reductions (DECC, 2014b) have occurred despite a growth in population and household numbers (Figure 2.3), and Figure 2.4 illustrates the general downward trend in average household energy consumption since 2004. In terms of the potential contribution of behavioural change to this observed decrease, a survey of energy-consuming behaviours found that over the 2007-2009 period the proportion of householders

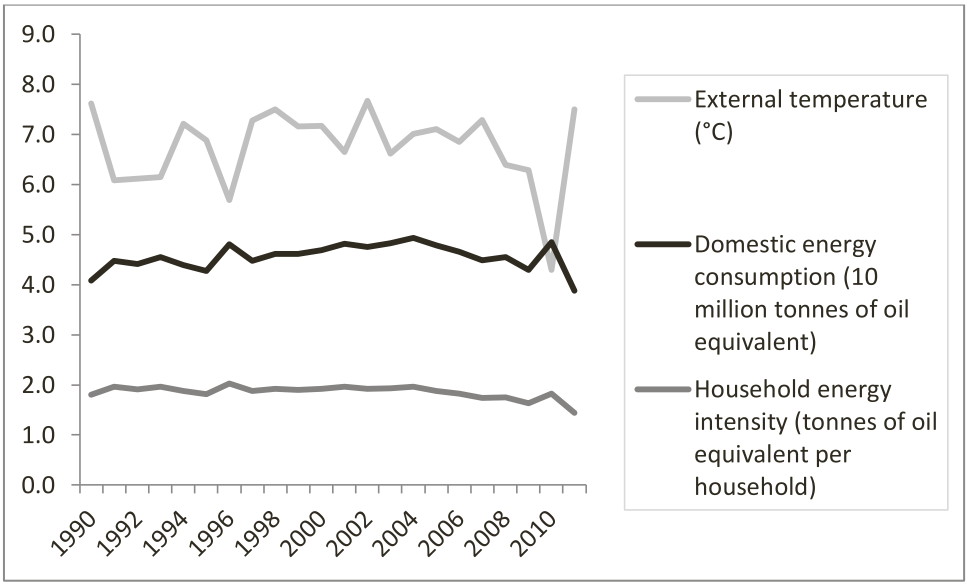

Figure 2.4. Trends in household energy intensity, domestic energy usage and external temperatures (1990-2011) (Source: DECC, 2012d)

who perceived they were reducing energy consumption rose from 58% to 76% (Defra, 2009). Associated actions reported included confining volumes boiled in kettles to that required, reducing thermostat settings and washing clothes at reduced temperatures (Defra, 2009). Research into factors that influence household energy-consuming behaviours is receiving increased attention from the social sciences (see, for example, Bartiaux, 2008; Dobbyn & Thomas, 2005; Georg, 1999; Gibson, et al., 2011; Gill, et al., 2010; Gyberg & Palm, 2009; Hargreaves, et al., 2013; Keirstead, 2007; Nye, et al., 2010; Owens & Driffil, 2008; Palm, 2010; Pyrko & Darby, 2011; Reid & Houston, 2013; Shove, 2003; Sorrell, 2009; Stephenson, et al., 2010; Wilhite, 2007; Wilson & Dowlatabadi, 2007; Wrapson & Devine-Wright, 2014) and pertinent aspects of such research is drawn upon in subsequent chapters.

Before 1981, the energy performance of new dwellings was 'essentially unregulated' (Clarke, 2008, p. 4606). Subsequently, energy performance standards have become increasingly challenging via the periodically updated Building Regulations (UK Government, 2010), the Code for Sustainable Homes (CSH) standard (DCLG, 2010) (as applied to social housing and to developments in certain planning authorities, for example), and via local planning policies that stipulate low carbon and renewable energy targets for new developments (see Section 2.4)[13]. Additionally, a series of Governmental schemes have sought to reduce energy demands within existing homes (DECC, 2010b) via the promotion of greater energy efficiency (recent examples

[13] Refer to Rydin (2010a) for a discussion on the impact of these changes on the development control and building control functions within local authorities.

being the Green Deal (DECC, 2012b; EST, 2013b) and Green Deal Home Improvement Fund (DECC, 2014c)), and via the promotion of on-site decarbonised energy generation (via the FIT (Ofgem, 2012) and the RHPP (EST, 2013a), for example).

Household energy demand is driven by the level of comfort (such as indoor temperature) and services that occupants strive for, as influenced by factors such as fuel affordability (Wright, 2008). The energy needed to attain desired standards will be determined by factors such as the building's location, orientation and built form; the installed energy-consuming equipment; and the occupant's behavior (for example, are windows left open whilst the heating is on) (Wright, 2008; DECC, 2013i). The occupant's role is influential at each of three stages: setting the standards of comfort and services expected; determining, through purchase, the energy-efficiency and number of appliances and lighting; and running the household (energy-wasteful versus energy-saving behaviours).

As regards future CO_2 emissions from the housing sector, both household numbers and emissions per household are relevant; the latter is turned to next.

Measures to reduce household emissions

Factors that will continue to contribute to lowering household energy consumption include improvements to the energy-efficiency of domestic appliances, lighting, heating systems and other electrical devices, and improvements to the thermal performance of building structures. Certain improvements have been required or promoted by regulations which have, for example, driven the development and uptake of more energy-efficient products (such as via the energy-labelling of domestic appliances and lighting (European Parliament, 2010a)) and the construction of dwellings designed to comply with higher energy performance standards. Future revisions to the Building Regulations will raise further the energy performance standards for new dwellings by 2016.

Another contributing factor has been the development of the CSH, a building code that has promoted sustainable design and construction. Introduced in 2007, the CSH has driven improvements in the energy performance of dwellings beyond Building Regulation requirements. The extent of its adoption has differed between regions and planning authorities and also between development types (as determined, for example, by the size of the development and whether the build is public or private sector). Achieving a specified level under the CSH (initially Level 3) has been required for social housing developments in England since 2007 (Housing Corporation, 2007) and Northern Ireland since 2008; within all residential developments in Wales since 2010 (and multi-unit developments since 2009) (Welsh Government, 2012); and within certain English planning authorities for specified sizes of development (with varying introduction dates). The recently published Housing Standards Review, however, signalled that the CSH may have a limited life as efforts are made to streamline the building process (DCLG, 2014a) and this has now been confirmed by the Government (DCLG, 2014b).

The progressive decarbonisation of household energy sources has also promoted emission reductions. Between the early 1990s and 2011, the natural gas proportion in the fuel mix powering UK electricity generators increased dramatically, mainly at the expense of coal (DECC, 2013i). As natural gas combustion has a lower CO_2 emission factor than coal or oil, this shift lowered CO_2 emissions per unit of electricity generated. In 2012, however, the world price for coal decreased and consequently UK coal usage increased; its combustion now contributes to 44% of generated electricity (DECC, 2013i). Additionally, CO_2 savings have been achieved through a reduction in electricity transmission and distribution losses that occur between the points of generation and consumption (Defra, 2012). Between 1990 and 2009, the combined effect of these trends has been a significant decrease in the CO_2 emission factor for mains electricity, declining from 0.766 kg CO_2/kWh to 0.517 kg CO_2/kWh (BRE, 2010). This decarbonisation trend was set to continue in the coming decade through the increased generation of electricity from renewable sources (DECC, 2011c) and a projected continued reduction in reliance on coal (BRE, 2011); however, the increased reliance on coal observed in 2012 is counter to these projections and may lead to revisions for the proposed CO_2e emission factor of 0.463 kg CO_2e/kWh for the 2016-2018 period (BRE, 2011).

Additionally, the renewable contribution to UK electricity generation rose to 11.3% in 2012 (DECC, 2013a) and is envisaged as potentially rising to 30% by 2020 (DECC, 2010a).[14] As well as larger scale installations, the decarbonisation of household energy sources is also being promoted through the deployment of on-site low carbon and renewable energy technologies (DECC, 2012c; DECC, 2013i), such as photovoltaics (PV), solar thermal hot water (STHW) systems and air source heat pumps (ASHPs), which are expected to become more prevalent through forthcoming upgrades to the regulatory building standards (Planning & Climate Change Coalition, 2012). These technologies (as listed in Table 2.1) are referred to in this thesis

[14] This percentage incorporates a 2% input from small-scale electricity sources such as on-site photovoltaics (PV).

as low and zero-carbon (LZC) technologies. The factors which influence how householders use, regard, and interact with these technologies are the focus of this research (as expanded upon in Chapter 3).

An additional factor that has the potential to contribute to reducing emissions is the adoption of less energy-intensive behaviours (Gram-Hanssen, 2013) and there has been a series of Governmental interventions aimed at lowering individuals' carbon footprints through such behavioural shifts. Such interventions range from non-regulatory and non-fiscal measures (such as the 'Act on CO_2' (Directgov, 2010) and 'Stand up to climate change' (Defra, 2008) multi-media information campaigns), through to fiscal measures (such as the FIT and the Green Deal) and regulation. Behaviours are understood as being shaped by a myriad of factors

	Heat output	**Electrical output**
Zero carbon generation[15]	Solar thermal hot water (STHW) (photovoltaic pump or thermosyphon)	Solar photovoltaic (PV) Wind Micro-hydro
Low carbon generation[16]	Solar thermal hot water (STHW) Biomass Heat pumps (air source heat pump (ASHP), ground source heat pump (GSHP)) District heating Micro or community combined heat and power (CHP)	
Energy efficiency	Mechanical ventilation and heat recovery (MVHR) Passive flue gas heat recovery device	

Table 2.1 Low and zero-carbon (LZC) technologies (EST, 2010a)

[15] Zero-carbon technologies are powered purely by renewable energy (such as solar and wind energy).
[16] Low carbon technologies include those that depend mainly on renewable energy to generate heat and/or electricity, whilst still requiring a certain amount of fossil-fuel derived energy to run key components (such as STHW pumps). They also encompass technologies that are reliant on fossil-fuels for their operation but, as they are significantly more efficient than conventional technologies, their associated CO_2 emissions per unit of power is correspondingly lower (such as with CHP). LZC technologies additionally include systems which extract and re-use the heat contained in indoor air (such as MVHR systems).

such as knowledge, habits, structural conditions, psychological traits and socio-demographic aspects (POST, 2010), and any attempt to change the nature and pattern of people's day-to-day activities is therefore a complex and uncertain undertaking, whose success may be hard to forecast or directly measure. One approach favoured by certain behavioural economists is libertarian paternalism (Gill & Gill, 2012), where individuals are nudged into making decisions that are beneficial to them and/or society ('social nudges' (Thaler & Sunstein, 2009, p. 75)), whilst retaining a freedom of choice in the given situation.

Projections of household CO_2 emissions

Projections indicate a 25% reduction in CO_2 emissions from the household sector between 1990 and 2020, given all the policy and legislative measures to be implemented (Climate Change Committee, 2008), and the reductions achieved to date are in line with this indicator trajectory (Climate Change Committee, 2012). In accounting for these projected emission reductions, a major contributing measure is identified as the sequential amendments that have and are scheduled to be made to the Building Regulations (DECC, 2011a), which are turned to next.

2.3 National legislation pertaining to housing standards

2.3.1 Incremental changes towards zero-carbon 2016

Forthcoming amendments to the Building Regulations will necessitate an increasing reliance on LZC technology to meet tougher CO_2 emission standards (Planning & Climate Change Coalition, 2012). It has previously been stated that the UK climate change policy goals provided 'an insufficiently clear basis for developing concrete short- and medium-term policies for the housing sector' (Lowe & Oreszczyn, 2008, p. 4476). This deficiency looked set to be addressed back in 2006 by the Government's target of requiring zero-carbon new homes by 2016 (DECC, 2010b), but the definition of what this constitutes has not held firm (McLeod, Hopfe, & Rezgui, 2012).

In order to attain this zero-carbon target, the stringency of the Building Regulations was raised in 2010 (UK Government, 2010) and 2013 (through revisions to Part L1a (HM Government, 2013)) and is being raised again in 2016. However, the extent to which the energy performance standard is actually being raised is now markedly lower than initially proposed

(McLeod, Hopfe, & Rezgui, 2012). In order to appreciate how this concept has become redefined, a brief overview of the salient points is provided in the following paragraphs.

At the outset, the zero-carbon home definition was that provided in the CSH's 2007 Technical Guide, wherein a 'true zero carbon dwelling' had zero net CO_2 emissions arising from *all* the dwelling's energy usage (DCLG, 2007a, p. 31). Whereas the Building Regulations have hitherto only regulated that portion of CO_2 emissions calculated to arise from fixed building services (which encompass space heating, water heating, fixed internal and external lighting, air conditioning and mechanical ventilation (HM Government, 2010)), known as regulated emissions, the 'true zero carbon dwelling' definition (DCLG, 2007a, p. 31) covered both regulated and unregulated[17] emissions (Greenwood, 2012). The latter pertains to any energy-consuming device not defined as a fixed building service, which encompasses movable lights, wet and cold appliances, cooking appliances and consumer electronics, for example.

In order to achieve zero net CO_2 emissions, a 'true zero carbon dwelling' (DCLG, 2007a) was initially allowed to make use of on-site LZC technology, off-site LZC technology (which were directly connected with the dwelling by a private wire arrangement) or accredited external renewables. This latter option was removed in October 2007 (DCLG, 2007b) to make the definition of a CSH zero-carbon home correspond with that issued by the Treasury (UK Government, 2007) for use by its stamp duty land tax relief scheme for zero-carbon homes (Pickvance, 2009; Bergman, et al., 2009).

Since October 2007, amendments to the zero-carbon home definition that will apply to the Building Regulations in 2016 have led to a progressive weakening of its requirements in terms of its coverage (WWF-UK, 2011; Greenwood, 2012; Pickvance, 2012; Goodchild & Walshaw, 2011) and in terms of what it allows as off-site solutions. The definition now excludes any account of unregulated CO_2 emissions[18] (NHBC Foundation, 2012b; BIS, 2011) and it will also allow a range of off-site measures to assist with the off-setting of regulated CO_2 emissions; the range of acceptable off-site measures, or allowable solutions, is still undetermined (DCLG, 2013). The Government's justification for this weakening of requirements is to ensure that 'it remains viable to build new homes' (BIS, 2011, p. 117); as Rydin (2010b, p. 83) notes, the protracted process of defining zero-carbon homes has been 'inherently political', and the

[17] The method currently stipulated for the estimation of unregulated emissions (DCLG, 2007b) employs a formula where the input variables are the total floor area of the dwelling and the number of occupants (as derived from the total floor area).
[18] Estimated in one study as accounting for 37-45% of household CO_2 emissions (Gill, et al.,2011).

Government has retreated 'to a more conservative approach', as warned against by the Calcutt Review (DCLG, 2007d, p. 89).

As it stands at present, a new dwelling coming under the Building Regulations from 2016 will need to meet a set fabric energy efficiency standard (relating to the thermal performance of the building envelope) and a carbon compliance target (whereby a set proportion of the regulated CO_2 emissions are off-set either by on-site LZC technology, connected off-site technology such as district heating, or by further improvements to the level of fabric energy efficiency achieved[19]) (Zero Carbon Hub, 2012b; McLeod, Hopfe, & Rezgui, 2012). The proportion of regulated CO_2 emissions that remain unabated after the carbon compliance target has been met can then be off-set by allowable solutions[20]. Despite the reduced stringency of the zero-carbon definition that now prevails, it is envisaged that new dwellings built beyond 2016 will, in the majority of cases, still be designed to incorporate on-site LZC technology and off-site technology such as district heating, in order to meet the carbon compliance target.

2.3.2 Issues with accelerated introduction of new technology

Prior to the 2010 revisions to the Building Regulations, the requirement to meet the Target Emission Rate for a dwelling (that is, the maximum CO_2 emission rate (expressed in kg CO_2 per m^2 per annum) permitted by the Regulations for any given building design) was unlikely to necessitate the inclusion of LZC technology (EST, 2006b). The targets were able to be met by reducing the thermal losses from the dwelling by improving, for example, the insulating properties of the building envelope and reducing air permeability rates (EST, 2006b). However, house-builders may increasingly turn to LZC technology to help their designs meet the tighter CO_2 emission standards required by the current Building Regulations (UK Government, 2010), but it is not a requirement. Indeed, it is deemed preferable to first improve the energy efficiency standards of a building (CABE, 2010; National Housing Federation, 2010) rather than rely on LZC technology to help an inefficient building design achieve the required standard.

[19] Such as via heightened insulation levels and reduced air permeability.
[20] An indicative list of allowable solutions includes 'retro-fitting of low carbon technologies in existing buildings' and 'investment in energy efficient infrastructure, such as low carbon street lighting' (DCLG, 2013, p. 30).

By 2016, with the arrival of the zero-carbon home requirement, the installation of LZC technology in new developments is likely to become commonplace nationwide (Planning & Climate Change Coalition, 2012). With the shift in energy technology configurations that will arise, it is advisable to consider and prepare for issues that may influence the CO_2 emission reductions achieved. Back in 2007, Walker & Cass's review of the emerging renewable energy landscape listed the underlying discourses behind household installations as being 'personal environmental responsibility', 'self-reliance' and 'autonomy' (Walker & Cass, 2007, p. 462). These motivations were attributed to the mainly active domestic installers at that time; we now need to consider the increasing number of householders in mainstream new housing that will encounter unselected, pre-installed LZC technology (Monahan & Powell, 2011; Rydin, 2010b).

2.4 Identifying the research opportunity

An early test-bed for the accelerated introduction of LZC technology is provided in local authority areas where innovative planning policies, known as the Merton Rule (Day, et al., 2009; Wilson, 2009; Williams, 2010; Bergman, et al., 2009; Boardman, 2007b; Rydin, 2010b), have been adopted. This policy is named after the London Borough of Merton, its first point of use, where in 2003 the following planning policy was introduced for non-domestic developments:

> 'All new non-residential developments above a threshold of 1,000 m^2 will be expected to incorporate renewable energy production equipment to provide at least 10% of predicted energy requirements.' (Merton Council, 2012)

Since 2003, 325 out of 390 English councils have adopted the Merton Rule, or variations of it (Merton Council, 2012)[21], and a proportion have extended its remit to include dwellings; such policies are referred to in this thesis as *LZC energy policies*[22,23] and they are, together with the Building Regulations, an illustration of how the governance of the low carbon building agenda is currently a 'multi-level phenomenon' (Bulkeley, Hodson, & Marvin, 2012, p. 115). The variations exhibited in the way local authorities have tailored and implemented this type of

[21] Reflecting a highly successful form of 'policy boosterism' (McCann, 2013, p. 9).
[22] Such policies were later promoted by national planning policies (DCLG, 2007c; ODPM, 2004) and the Planning and Energy Act 2008.
[23] Such policies apply to both regulated and unregulated energy consumption, unlike the current zero-carbon home concept (Boardman, 2007b).

planning policy are significant (see Section 5.3)[24] and are an example of how geographical differences in the UK's low-carbon energy transition have emerged (Bridge, et al., 2013). In terms of the policy's breadth of application, this is greatest where authorities have encompassed *all* new dwellings, regardless of development size. The existence of these localised policy test-beds (where there has been an accelerated introduction of LZC technology compared to other authorities with no such policy in place, or with more lenient versions adopted) provides a research opportunity for those seeking to assess the potential consequences of the scheduled changes to the Building Regulations, as noted by the Calcutt Review (DCLG, 2007d). Conducting research within these test-bed areas, as this research does, provides an opportunity to identify any problem issues, investigate the potential causes of these and highlight where improvements can be made.

As mentioned in Chapter 1, undertaking borough-wide research generates insights into the breadth of issues emanating from the incorporation of a range of LZC technologies into various dwelling types with different tenure arrangements and household compositions. The literature review in the next two chapters explores the current state of knowledge in this field to which this research seeks to contribute and extend.

[24] Representing an example of what McCann & Ward term (2012, p.43) 'policy mobility and mutation'.

Chapter 3: The state of LZC technology-user relations

3.1 Introduction

In Chapter 2, I reviewed the international agreements, legislation and policies linking climate change concerns with the introduction of LZC technology into new homes. This provided an appreciation of this technology's role, in and amongst the myriad of other measures being taken to reduce greenhouse gas emissions. Our understanding of how effective the LZC technology-householder association will be in delivering envisaged reductions in CO_2 emissions is, however, incomplete.

In this chapter, I turn to the academic research which contributes to current understandings of how householders come to use, regard, interact with and be influenced by LZC technology. Through this review, various knowledge-gaps are identified and used to inform the research questions guiding this study. By addressing these questions, the research contributes to the extant literature.

Studying how LZC technologies are used and their influence on users requires a consideration of relations that span across the social and technical realms. An approach well-suited to such considerations is the technology studies version of domestication theory, introduced in Section 3.2.1 The review then focuses on how LZC technology re-configures domestic energy systems in physical, visual and symbolic ways (Section 3.3). Section 3.4 considers the many physical, technical, social, and cognitive factors that influence how LZC technology-householder associations develop in any particular setting. It takes effort to sustain the physical integrity of technologies prone to on-going decay (Graham & Thrift, 2007) and Section 3.5 examines the research pertaining to the maintenance and repair of LZC technology. Whether householders change their everyday routines[25] due to LZC technology is discussed in Section 3.6.

The chapter then reviews research that emphasises the need to learn from householders as to why they interact with LZC technology as they do; gaining such insights provides opportunities for policy-makers, developers and designers to appraise how they might intervene to improve the design, installation and use of these technologies.

[25] Gram-Hanssen (2008, p.1188) defines routines as the 'smallest parts of the social organisation of everyday life.'

3.2 A socio-technical perspective

3.2.1 Introduction

A socio-technical perspective has been adopted in this review. A particular body of this work has guided the research's design, execution and analysis and thus serves as an applicable lens through which to review previous research of relevance. The socio-technical perspective emanates from science and technology studies (STS), which give attention to how technologies are shaped by social-technical processes (during their design and use) (Rohracher, 2003; Schweber & Harty, 2010) and also to how technologies shape the situations in which they become embedded (Wilhite, 2007).

The specific socio-technical approach adopted is the technology studies version of domestication theory (Sørensen, 2006), which can be used to study the ways in which LZC technologies are used and their influence on users. This approach combines domestication theory (Sørensen, 2006; Silverstone, 2006) with aspects of actor-network theory (ANT)[26] (Latour, 2005). In studying socio-technical associations, attention can centre on the technology and its socio-technical relations or the user and its socio-technical relations[27]; domestication theory focuses on the latter (Silverstone, Hirsch, & Morley, 1992) and ANT studies often focus on the former (see Section 4.2). Aune (1996, p.93) views domestication theory as embodying a 'periphery-centre perspective', which focuses on how users engage with technology on different levels, wheras ANT embodies a 'centre-periphery perspective', which focuses on the designers' intentions for users. Pertinent concepts from domestication theory and ANT will be introduced throughout this chapter.

This study is interested in, firstly, the extent to which LZC technology, householders and other associated entities impact on, or configure, each other; secondly, how the extent of this 'mutual shaping' (Coutard & Guy, 2007, p. 718; Law & Callon, 1992, p. 25) varies between households and between technology types (Bergman & Eyre, 2011); and, thirdly, the factors that contribute to the variations observed. Together, the LZC technology, householders and associated entities, that impact on the technology's use and are impacted by its use, comprise

[26] ANT's focus of study specifically encompasses both human and non-human entities (such as texts, technical artefacts and material structures (Sayes, 2014)), their actions and their ability to influence the actions of other entities. When applying this so-called methodologically (Sayes, 2014) symmetrical approach (Preda, 1999), all entities within the field of study are of potential interest at the outset – the significance that any entity has (in contributing to research objectives) is not pre-judged based on its (non)human status.

[27] Both of which can be considered as 'socio-technical ensembles' or 'local or micro-level' actor-networks (Sætnan, 1996, p. 35).

the research 'setting' (Akrich & Latour, 1992, p. 259). A wider question to address (Coutard & Guy, 2007; Gad & Jensen, 2010; Neyland, 2006) is whether LZC technology-householder associations perform as envisaged by policy-makers, who instigated their alliance for CO_2 reduction purposes[28]? If not, what opportunities are there to strengthen, forge new or sever associations to achieve further CO_2 reductions?

3.2.2 LZC technology & the wider socio-technical network

LZC technology in new dwellings reside at the notional interface between three phases of a wider socio-technical network. The *first network phase* incorporates entities such as planners, building control officers and policy instruments that require and verify (or not) the technology's installation, through which the planning authority can demonstrate its commitment to reducing CO_2 emissions (Keirstead & Schulz, 2010). The presiding discourse[29] here relates to climate change (or 'carbon control' (Eadson, 2012, p. 67)) and, to a lesser extent, fuel poverty (EST, 2011a; Jones, et al., 2000) and energy security (Pyrko & Darby, 2011).

The *second network phase* centres on developers, architects, house designs, technology specifications and other entities whose collective contributions shape the technology as installed. For speculative developers, this installation typically represents a precondition for attaining planning permission[30], whilst still building profitable (Osmani & O'Reilly, 2009a; Fischer & Guy, 2009; Carmona, 2009) and marketable dwellings (HCA, 2011; Pickvance, 2012; Guy & Shove, 2000), with little change to established modes of construction (Williams, 2010). The discourse here is mainly an economic one (Munzinger et al, 2006; Imrie, 2007; Carmona, 2009; Pickvance, 2009 & 2012; Pan & Cooper, 2011). Within the social housing sector, the discourse centres on addressing fuel poverty through energy cost reductions (Munzinger et al, 2006; Abdel-Wahab, Moore, & MacDonald, 2011), in addition to decreasing CO_2 emissions (EST, 2011a).

[28] Speaking of machines and devices, Akrich (1992, p.205) states: 'Although they point to an end, a use for which they have been conceived, they also form part of a long chain of people, products, tools, machines, money and so forth.'
[29] Discourses can be 'considered as patterned ways of speaking and acting which determine not just what gets decided, nor what it is safe or important to discuss, but what can be discussed without being mad, incomprehensible, or lacking in common sense' (Reason, et al., 2010, p. 96). See also Gyberg & Palm (2009).
[30] LZC technologies will increasingly be installed to help comply with tougher Building Regulations and existing LZC energy policies will become phased out (Section 2.3).

The *third network phase* centres on householders and pre-installed LZC technology. For householders, the technology may represent a means to save on energy costs (Walker, 2008a), improve levels of comfort (Gram-Hansen, Christensen, & Petersen, 2012) and/or contribute to reducing CO_2 emissions (Caird & Roy, 2010), for example. As householders move in, the wider 'heterogeneous assemblage' (Marres, 2010, p. 187) of previously associated entities that affected the technology's installation (such as electricians and plumbers) may already be beyond easy reach[31], and the way householders use LZC technology may not concur with assumptions made when forecasting compliance with CO_2 emission targets[32].

The variance in meaning assigned to LZC technology within these constitutive phases of the wider socio-technical network highlights the technology's' 'interpretative flexibility' (Pinch & Bijker, 1989, p. 29, Sætnan, 1996, Kline & Pinch, 1999, Paredis, 2011). What implication, though, does any discontinuity between meanings have on how LZC technology is installed? Whether developers promote the optimisation of these technologies through a well-considered design, installation and hand-over process, which pays attention to the installed spaces, associated devices and future users, will be examined in this research.

To summarise, LZC technologies reside at a notional interface, or boundary, between the constitutive phases of a network (centred on the planning process, the development process and habitation), where the boundary is a relational effect[33] (Lepawsky & Mather, 2011) and one where there may be a discontinuity in meaning associated with the technology.

3.3 Physically, visually & symbolically re-configuring the home

With the deployment of LZC technology, a new type of public is emerging; one where householders are becoming physically implicated (Marres & Lezuan, 2011) in policy-makers' efforts to tackle climate change (discussed in Chapter 2). For example, where the technology displaces, rather than supplements, conventional energy systems, a physical reliance on the technology is configured into the socio-technical structure of the home. In addition, users may

[31] Where work on-site has finished.

[32] Outputs from SAP (BRE, 2014) are used to demonstrate compliance with Building Regulations (UK Government, 2010) and may also form part of the evidence base for demonstrating compliance with LZC energy policies.

[33] Lepawsky& Mather (2011) argue that boundaries are not pre-defined but are contingent upon the prevailing relations (or actions) in a setting and therefore they require explanation.

need to actively attend to the technology to ensure its correct functioning (Smith & Stirling, 2007).

Since the advent of the National Grid and the gas distribution network, the provision of domestic energy services has been mainly met through these two energy infrastructures that transport electricity and natural gas seamlessly into our homes. The technological diversification of energy systems is now increasing with the range of LZC technology being installed (Moss, 2009). Certain technologies, such as centrally-managed CHP[34] which serves multiple dwellings, may retain some of the characteristics associated with conventional energy infrastructures, including the relative invisibility of such infrastructure to householders (Shove & Chappells, 2001). Others are more visible, as with ASHPs[35] (typically sited in gardens) and biomass boilers (where the biomass store will need periodic replenishment). Thus, certain LZC technologies will increase the visibility of energy generation and provision (Nye, Whitmarsh, & Foxon, 2010; Dobbyn & Thomas, 2005).

For some householders, LZC technology will potentially provide a means of symbolically relating to efforts to combat climate change. This point is taken up by Marres (2010, p.179), who discusses the ability of domestic energy technologies, such as thermostats, to potentially dramatise 'connections between practices "in here" and changing climates "out there"', enabling householders to act-out their participation in addressing climate change. For others, such 'affordances' (Akrich & Latour, 1992, p.261; Latour, 1994; Marres, 2010; Sørensen, et al., 2000) may remain untapped, potentially due to poor understandings of the technology or disinterest in climate change. The symbolic meaning ascribed to LZC technology may deviate from that ascribed to it by policy-makers and it may vary between and within households (Reimer & Leslie, 2004).

Studies on LZC technology have centred mainly on retrofits, where the drivers and barriers to adoption, user satisfaction levels and modes of use are typically considered (Caird & Roy, 2010; Wrapson & Devine-Wright, 2014; Devine-Wright, et al., 2014; Owen, Mitchell, & Unsworth, 2013; Faiers, 2009). Active retrofitters[36] within private housing are termed early adopters; they are typically motivated by the prospect of lowering energy costs, reducing CO_2 emissions or demonstrating their commitment to the environment (Caird & Roy, 2010;

[34] Refer to http://www.chpa.co.uk/what-is-chp_15.html for an explanation of CHP technology.
[35] Refer to http://www.energysavingtrust.org.uk/Generating-energy/Choosing-a-renewable-technology/Air-source-heat-pumps for an explanation of ASHP technology.
[36] Those living in retrofitted social housing are alluded to (in the academic literature) as passive retrofitters as the decision to retrofit is the landlord's.

Wrapson & Devine-Wright, 2014). Such users are considered unrepresentative of the wider population in their degree of commitment to these technologies (Rohracher, 2003).

Other research has focused on residents within specific new developments with high environmental credentials (often termed eco-housing) or especially low energy requirements (such as passive houses (Mlecnik, et al., 2012; Zalejska-Jonsson, 2012)). Such housing is unrepresentative of mainstream new housing fitted with LZC technology to meet a LZC energy policy (Section 2.4). An under-researched area pertains to how those moving in to these mainstream new builds view this technology and whether their outlook on it influences how they make use of it.

Research question: What symbolic meanings do new home occupants attach to LZC technology, and do these ascribed meanings affect how the technology is used? (→ Section 9.4)

3.4 LZC technology-user relations

3.4.1 Visions of end-users

Depending on how LZC technology has been designed and embedded within a socio-technical network, there may be multiple ways of using it that yield varying CO_2 reductions. Whether users follow the preferred (or optimum) mode of use will depend upon how well this option is scripted into the technology-user interface; that is, how 'explicit' the 'prescription'[37] is (Jelsma, 2003, p. 107).

Where a designer has enabled only one form of deployment, the prescription is considered 'rigorous' (Brand, 2005a, p. 11) or 'strong' (Jelsma, 2003, p. 109), and the 'program of action delegated' (Latour, 1992, p. 233) to the user is made clear. Where the technology's design allows for different modes of use (as with summer, winter and boost settings for MVHR systems[38]), the inscription for the (seasonally dependent) preferred form of use needs to be clear in order to enrol users. As summarised by Oudshoorn et al. (2004, p.55):

> 'In using technologies, users do not necessarily have to adopt the scripts constructed by the designers. Users may slightly modify the scripts, they may drastically transform them, or they may even completely reject them …'

[37] The definition of prescription provided by Latour (1992, p.232) is 'the behaviour imposed back onto the humans by non-human delegates.'

[38] Refer to Zero Carbon Hub (2012a) for an explanation on MVHR systems.

At this point, it is useful to introduce some further terms to characterise associations between entities:

> 'Subscription (…): the reaction of the anticipated actants[39] – human and non-humans – to what is prescribed or proscribed to them.' (Akrich & Latour, 1992, p.261)

Where a user adheres fully to the prescribed mode of action presented by a technology, the user's subscription meets the prescription's requirements. Where there are discrepancies between prescriptions and subscriptions, efforts to reduce these can be characterised as a form of 're-inscription' (Akrich & Latour, 1992, p. 262), which can centre on the user, the technology or other entities within the setting.

Firstly, work can be undertaken to endow users with additional competences that enable them to follow prescriptions more closely (such as through training or information provision relating to their LZC technology). Secondly, re-inscription efforts may focus on improving the clarity with which the preferred mode of use is inscribed into the technology-user interface (Jelsma, 2003), through more intuitive control designs, for example. Lastly, re-inscription efforts may target other entities that either *impede* users from following prescriptions or could *encourage* them to do so (such as getting developers to explain LZC technologies to new home occupants). This last option targets the wider factors that contribute to the configuration (Woolgar, 1991) of technology-user relations (Aune, 2007). In her study on PV installations, for example, Ghanem (2008) illustrates how users are configured both by the ways in which the system's components (particularly the display monitor) are embedded in the buildings' design and by documentation handed over. So, re-inscription acts on knowledge gained about the discrepancies between prescriptions and subscriptions. The nature and underlying cause of these discrepancies will help determine the field of focus for re-inscription efforts; throwing light on these discrepancies in the context of LZC technology-user associations is one of the objectives of this research.

Research question: How are users configured by the design, placement and settings of LZC technology (→ Section 7.3)

In determining how to inscribe technology, the design process may be influenced by a particular vision of an end-user (Jelsma, 2003; Ornetzeder & Rohracher, 2006) and the competences and interests/values assigned to this idealised end-user may partially determine the inscription employed (Akrich, 1992). However, these assigned characteristics, possibly

[39] Defined in Section 3.6.1.

reflective of the designers' own competences and experiences (Ornetzeder & Rohracher, 2006; Berker, 2011), may be unrepresentative of many end-users; that is, 'there might be an enormous gap between the prescribed user and the user-in-the flesh' (Latour, 1992, p. 237). This disparity may adversely affect the degree to which these unconsidered user types are able to, or can be persuaded to, follow the inscription encoded into technology (Oudshoorn, Rommes, & Stienstra, 2004). Rohracher (2003) considers these unconsidered types in his research on MVHR systems in Austria. He notes that 'early users who are involved in shaping technical systems often belong to specific social groups' and that these are 'generally more highly educated, more wealthy and showed more environmental commitment than average people' (Rohracher, 2003, p. 189).

It is not just end-users who may be at odds with designers' visions: the wider socio-technical network responsible for installing the technology may be deficient (Rohracher, 2003). In discussing how MVHR systems move from the innovative stage to one of wider adoption in Austria, Rohracher (2003, p.183) comments that:

> 'the practice of planning and implementing ventilation systems has to change on the way from highly specialized designers and producers to less competent installers.'

Evidence for inadequately designed and installed LZC technology is emerging in the UK (Zero Carbon Hub, 2012a; NHBC Foundation, 2012b), with one survey attributing blame to installers for 90% of detected faults (NHBC Foundation, 2012b). Such research suggests that increasing installation rates for LZC technology 'would seriously test the skill base of tradesmen involved in their installation, maintenance and repair' (Nye, et al., 2010, p.709). In recognition of observed deficiencies in installers' skill base, DECC (2011b) signalled that competence requirements needed swiftly to be incorporated within the MCS for installers and the Building Regulations' Competent Person Scheme.

Returning to end-users, designers may bestow them with values that will motivate them to use the technology optimally[40], and this may adequately represent some. A user's motivation, however, may be insufficient to overcome constraints imposed by other entities. Additionally, although a user may hold values conducive to using a technology optimally, this may not transpire where there is insufficient understanding of the technology and the finer points of the user's intended role. As Gram-Hanssen (2010, p.185) observes from researching residential heat consumption in Denmark:

[40] Such as wanting to maximise financial and environmental gains.

> 'It is absolutely possible to be highly engaged in the environment without knowing technically how to influence the level of consumed energy, as it is also possible to be technically interested in doing 'the right thing' without being especially environmentally concerned.'

This finding concurs with research on homes fitted with MVHR systems and biomass district heating in the UK (Gill, et al., 2011); here, even where a resident was *striving* to become a low energy consumer, they were the second highest energy consumer in the study, illustrating that environmental committment alone is insufficient to yield improvements if accompanied by constraints such as inadequate information (Gill, et al., 2011).

In addition to values, motivations and understandings, householders' competences are also of relevance. The National Housing Federation (2010), for example, advocates that housing associations consider householders' likely ability to undertake any simple maintenance tasks required for installed LZC technology. Notions of competency are explored in the following two sections.

3.4.2 Black boxes & immutable mobiles

Akrich (1992) presents a broad perspective on competency. She contends that, in designing for a technology's preferred form of deployment, designers need to decide how to distribute the necessary 'competences' (Akrich, 1992, p. 207) to achieve this. Where the ways of using a technology are severely restricted, or closed down (Mackay & Gillespie, 1992), the designer has assigned the bulk of the relevant competences to the technology, not the user. Where complete stability is attained in the outcomes achieved, the technology is termed a 'black box' (Latour, 1994, p. 36).

When a technology retains this black-box status wherever located, it is sometimes termed an 'immutable mobile' (Law & Singleton, 2005; Latour, 1986). Such technology is designed to be sufficiently understandable and usable in a consistent way or, alternatively, immune to a user's indifference. For example, national gas and electricity networks infiltrate seamlessly into homes and, in the absence of faults, householders black-box these technologies which, through their prevalence and consistency in use, can be considered as immutable mobiles[41].

[41] In discussing immutable mobiles, Law & Singleton (2005, p.335) outline how such an entity retains its shape in two distinct ways: 'On the one hand, it does so in physical or geographical space. On the other, it holds its shape in some relational and possibly functional manner where it may, to say it quickly, be imagined as a more or less stable network of associations.'

In the context of endeavours to reduce CO_2 emissions via the despatch of LZC technology into new homes, the success of this attempt at 'long-distance control' (Law & Singleton, 2005, p. 335) will depend on the degree to which such technologies function as immutable mobiles. For this to occur, socio-technical networks would need to be re-configured such that associations fully supported the LZC technology's correct use, wherever its location. In so doing, existing associations might need altering, or severing, and new associations formed to stabilise the new technology's use.

The stability attached to an immutable mobile is not considered to remain constant over time without some form of input, however. In other words, 'it takes *effort* to sustain stable networks of relations' (Law & Singleton, 2005, p. 337) and this is discussed in Section 3.5.

3.4.3 Distributed competences & distributed inscriptions

As possible modes of use increase, or open up (Mackay & Gillespie, 1992), the user requires a deeper understanding of the LZC technology in order to knowingly optimise its use; here, the designer allocates more requisite competences (Akrich & Latour, 1992) to the user or, as Ilmonen (2004, p.32) describes it, 'the more competencies' the technologies 'demand of us'. This 'distribution of competences' (Latour, 1992, p. 233; Akrich, 1992, p. 207), as materialised by designers in the forms the LZC technology and envisaged user take, amounts to a 'specific geography of responsibilities' (Akrich, 1992, p. 207) for operating the technology optimally. The preferred deployment mode may not be apparent to the user, however, dependent on how the LZC technology is scripted and on whether the user comes to read and understand that script.

What happens, then, when a user misinterprets the designers' intentions and mistakenly considers that a LZC technology operates optimally without their intervention? Incorrectly ascribing a black-box status to a technology that is designed to operate with some user involvement may lead to sub-optimal outcomes. For example, if MVHR systems are inadequately maintained by neglecting filter changes, their performance will deteriorate (Zero Carbon Hub, 2012a). In such instances, technologies may be sufficiently embedded within the physical infrastructure, but their 'social embeddedness' (Schweber & Harty, 2010, p. 659; Brand, 2005b) is lacking.

The inscription on how best to use a LZC technology may be shared amongst several entities, such as an instruction manual and control unit. The importance of such distributed inscription for LZC technology is acknowledged by DECC (2011b, p.5), who advocates a 'whole system' approach, requesting 'clear guidance' from industry to cover the technologies and associated controls. For example, the presence of well-written and comprehensive procedures, *if followed*, would facilitate users' enrolment into following the preferred mode of use.

Where the desired 'framework for action'[42] (Akrich, 1992, p.208) is not followed, the user's associations can be investigated to establish which might be ineffectively supporting the preferred mode of use. Potentially, associations designed to shape the new desired 'framework for action' may be thwarted by the dominance of 'more robust existing associations' (Harty, 2010, p. 313)[43]. Within any given setting, there may be numerous entities that influence the use and function of a LZC installation; some will be part of the designed set of devices (which I term the *formal* distributed inscription) and others will be external to this (which I term the *informal* distributed inscription). The presence and nature of associations that have an influence on technological performances will vary between settings, resulting in 'a multiplicity of enactments' (Gad & Jensen, 2010, p. 65), and the identification of these influential associations is a focus for this research.

3.4.4 Trials & distributed user engagement

The processes by which unfamiliar technologies become enrolled into household settings has been termed 'domestication' (Oudshoorn, Rommes, & Stienstra, 2004, p.55) and domestication theory constitutes another socio-technical approach (Gram-Hanssen, 2011; Oudshoorn & Pinch, 2005) that attempts to disentangle the complex processes behind the formation of technology-user relations (Aune, 1996). As discussed in Section 4.2, this research employs a 'technology studies version' of domestication theory (Berker, et al., 2006, p. 10), which combines the latter with ANT's sensibilities. With domestication theory, the adopted starting point is the user as opposed to the technology and its intended mode of use. As described by Lie & Sørensen (1996, p.8):

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[42] Akrich (1992, p.208) describes how 'technical objects define a framework for action together with the actors and the space in which they are supposed to act.'

[43] Such as when householders continue to rely on conventional energy systems, rather than testing out the capabilities of LZC technology in isolation.

> 'In everyday settings, we consume technologies – or, more precisely, technical artefacts – by integrating and using them. We are also consumed by the artefacts when they gain our attention and have us react to them and become occupied by their abilities, functions and forms. This dual relationship between humans and technologies is the outcome of a process of *domestication*.'

Lehtonen (2003, p.364) interprets domestication as a series of 'trials' which concern the user, the technology and the myriad of connected entities that impinge on the technology's use (Lehtonen, 2003). The term trial is pertinent as it suggests both an indeterminancy, or 'openness', with respect to outcomes and also a dynamic exchange between entities (Lehtonen, 2003, p. 381). Lehtonen (2003) proposes that attention should be paid to the conditions within a setting that allow for trials to ensue and also to the learning that is enabled through them.

A series of trials and associated outcomes suggests a series of disruptions and reconfigurations to the technology-user association until a period of relative stability prevails. An additional issue to consider in this research, then, is what trials have occurred and whether the LZC technology-user association within any particular setting has become stabilised. Even those that have rejected or are indifferent to the technology could be said to have reached some form of (dis)agreement.

Research question: What trials (experiences, interactions or receipt of new knowledge) trigger householders to shift and re-stabilise their socio-technical relations as part of the on-going domestication process? (→Sections 7.5 & 10.6)

Another consideration is how engagement with LZC technology becomes distributed amongst household members and whether there are any discernible patterns. As argued by Oudshoorn et al. (2004, p.32):

> 'Technologies may create new identities, or transform or reinforce existing identities, by delegating and distributing specific responsibilities, skills, and tasks to users.'

Where there are householders of different genders, how are LZC technology-related responsibilities distributed and does this alter existing distributions of competences and responsibilities as regards technology use? Technology is deemed 'one of the most stable and powerful symbols of masculinity' (Oudshoorn, Rommes, & Stienstra, 2004, p.53) and the competent use of technology has been aligned with what it means to be masculine (Berg & Lie, 1995).[44] How might the domestication of LZC technology differ between women and men and how might this process be negotiated? Lie & Sørensen (1996) consider that issues of gender may be encompassed, but not necessarily explicitly drawn attention to, when notions such as familarity, interest and competence are discussed. With newly introduced technologies, possibly yet to be 'assigned gender characteristics', the 'gendering process' (Sætnan, 1996, p. 37) may be more discernible and open to study as the technologies mediate household relations in potentially new ways (Lehtonen, 2003), stabilising or destabilising gender relations (Berg & Lie, 1995). Pink (2004, p.43) argues that:

> 'By seeing gender as partial and completed only in interactions with other individuals, objects or spaces, we can begin to think of individuals' housework practices as performative actions through which they might self-consciously constitute and re-constitute their gendered identities.'

A gendered disparity regarding 'environmental concern, values, and perceptions of environmental risks' has been observed (Norgaard & York, 2005, p. 508; Eisler, Eisler, & Yoshida, 2003; Whitmarsh, 2011), though how this influences the distribution of sustainability work within the home needs better understanding (Gibson, et al., 2011; Reed & Christie, 2009). In mixed households, environmental actions requiring a change to everyday routines tend to be the woman's responsibility (Reed & Christie, 2009), whilst those requiring structural work reside with the man (Scott, 2009; Organo, Head, & Waitt, 2012; Mansouri-Azar, 1996); the former finding is unsurprising given that housework is still predominantly undertaken by women (Berg, 1999; Sullivan, 2000).

3.4.5 Modes of engagement

Neighbourly support

Within developments where multiple dwellings have LZC technology, technology-related support may emanate from neighbours, rather than from friends and family lacking the necessary technological experience. This was observed in Monahan's (2013) research on a UK development containing 13 dwellings with various LZC technologies, where neighbours discussed their experiences with their technologies and their modes of operation. Where there

[44] MacKenzie & Wajcman (1999, p.273) suggest that whilst white goods (domestic appliances) 'are portrayed as serviceable and simple to use, brown goods are often portrayed as complex, clever technologies that require skills in handling.' Brown goods include entertainment-oriented technologies such as televisions.

is neighbourly support, relations may develop in ways that might otherwise not have occurred, contributing to denser and more varied associations. The extent to which neighbours provide LZC technology-related support to each other, such as through the exchange or transfer of experiential knowledge, and how this may be related to the development's characteristics (including 'spaces or possibilities to mingle and connect' (Marcus, Neumark, & Broome, 2011, p. 12)), appears unexamined in any depth. Similarly unexamined is the role that Residents' Associations may be playing in facilitating the exchange of useful information and the formulation of neighbourhood norms (Nassauer, Wang, & Dayrell, 2009).

Research question: To what extent do households in a given development provide LZC technology-related support to each other? (→ Section 9.3)

Research question: What role do Residents' Associations play in facilitating information exchange and assisting with formulating neighbourhood norms? (→ Section 9.3)

Unawareness, indifference, discontent, misuse and rejection

Given that new home occupants have typically not been involved in their LZC technology's installation, they may in certain instances be unaware of its presence, representing 'unwitting users' (Rose & Blume, 2005, p. 108). Others may be indifferent to their technology, labelled as '24/7 oblivious' by Dobbyn & Thomas (2005, p.38). EST (2011a) research on the success of LZC technology projects in social housing found that tenants became frustrated when they did not understand how to use their technology. Discontentment also arises when the technology presents a nuisance, as can occur with noisy (van der Pluijm, 2010; NHBC Foundation, 2013a; Zero Carbon Hub, 2012a) and draught-inducing (Monahan & Powell, 2011; NHBC Foundation, 2013a) MVHR systems, for example. Other householders may be misusing their LZC technology; for instance, Dobbyn & Thomas (2005) cite a passive STHW[45] adopter who had not had the system explained to her and as a consequence left the immersion heater constantly on. As highlighted by Mackay & Gillespie (1992, p.698), individuals 'are not merely malleable subjects who submit to the dictates of a technology' and they may reject, or otherwise resist, the technology imposed upon them (Mackay & Gillespie, 1992; Oudshoorn, 2012), becoming non-users. Such non-users have received significantly less consideration within STS than users (Oudshoorn, 2012; Wyatt, 2005).

[45] Refer to http://www.energysavingtrust.org.uk/Generating-energy/Choosing-a-renewable-technology/Solar-water-heating#2 for an introduction to STHW systems.

At this point, the concept of ‘antiprograms’ (Akrich & Latour, 1992, p. 261) can assist with examining acts of indifference, misuse and rejection. This term is defined as:

> ‘the programs of actions of actants that are in conflict with the programs chosen as the point of departure of the analysis; what is a program and what is an antiprogram is relative to the chosen observer.’ (Akrich & Latour, 1992, p.261)

This relativity of anti-programs can be illustrated as follows. Where a householder uses a LZC technology in a way that they understand to be correct, from their perspective they are following the intended program of action and there are no intentional anti-programs at play. If this householder has misinterpreted how best to use the LZC technology and is actually following a course of action unintended by designers, then there are anti-programs at play from the designers’ perspective. Thus, whether an action is an antiprogram depends on the point of reference, and anti-programs can be both intentional and unintentional. Where there is intentionality, the notion of ‘buildings at odd with inhabitants’ (Powells, 2009, p. 2348) is an applicable one.

As an example, several anti-programs (which could be intentional or unintentional) may counteract potential energy savings from MVHR systems; such as when occupants open windows (Rohracher, 2003; Macintosh & Steemers, 2005; NHBC Foundation, 2012b); ‘rely on additional heating facilities’ (Rohracher, 2003, p. 181); disable the system (Macintosh & Steemers, 2005; Monahan & Powell, 2011); operate it continously in the more energy-intensive mode designed to be used for short periods only (Macintosh & Steemers, 2005); and utilise the induced-draughtiness as a cooling mechanism in summer (Monahan, 2013).

Typology of the LZC technology user

In order to capture the variety of ways in which users interact with LZC technology, researchers have put forward certain typologies. From research on passive PV installers (which encompassed retrofits in social housing and new private builds in the UK), Ghanem (2008, p.175) proposes four types of users; ‘conscious’, ‘opportunistic’, ‘interested’ and the ‘non-user’. The ‘conscious’ user reported an increased awareness of energy consumption and Ghanem (2008, p.177) attributed this raised awareness to the ways in which the PV system had been embedded in the home, particularly with regards to the visibility of the display panel which enabled the user to track energy generation and usage. The ‘opportunistic’ user was found to increase electricity consumption during periods when the PV system was generating electricity. Sometimes this was viewed as an illustration of load shifting, when the timing of routine activities was re-aligned with the system’s performance. In other instances, the ‘opportunistic’ user was viewed as undertaking additional electricity consuming activities at times of peak generation that they might otherwise not have done (such as making use of the tumble dryer) (Ghanem, 2008, p. 179), demonstrating a rebound effect[46]. The ‘interested’ user (Ghanem, 2008, p. 181) demonstrated a fascination with the technology that extended beyond its environmental and economic attributes, and centred on the technology itself and its energy-generating potential.

The ‘non-user’ category was sub-divided into ‘passive non-users’ and ‘active non-users’, where Ghanem (2008) argues that the former were excluded from interacting with the technology by the way it had been configured in the home (such as display panels positioned in communal hallways rather than within the home); in other words, their non-user status was scripted by the design of the system and did not constitute an active choice (Ghanem, 2008, p. 183). Those that selected not to engage with the PV system, through disinterest or notions of inappropriateness, are what Ghanem (2008, p.183) calls the ‘active non-user’. It should be noted, however, that Ghanem’s (2008) non-users are still benefiting from, and therefore using, the PV system in that they are continuing to consume or export the electricity thus generated. Thus, I would suggest that the term non-user in this context is a misnomer.

In Caird et al.’s (2008, p.152) research on active installers of certain LZC technology, three categories of user were derived: ‘engaged’, ‘non-engaged’ and ‘reject-users’. The ‘engaged’ users were characterised as those that amended their behaviour so as to use their technologies effectively without creating any rebound effects; ‘non-engaged’ users were characterized as using their technology ineffectively; and ‘reject’ users were those that had adopted a LZC technology, used it but then rejected it (Caird, Roy, & Herring, 2008, p. 152; Roy, Caird, & Potter, 2012).

It is not the intention of this research to produce new, or verify existing, generic user typologies; however, within Section 7.4, specific typologies are generated to capture how householders engage with, and are shaped by, feedback from selected LZC technologies.

[46] Rebound effects are returned to in Section 3.6.1. Put simply, a rebound effect occurs where using LZC technology leads to increases in users’ expectations of levels of energy service provision.

3.5 Maintenance & repair

3.5.1 Maintaining systems & attending to faults

It takes effort to sustain the physical integrity of technologies prone to on-going decay (Graham & Thrift, 2007). Whatever form of physical stability prevails initially, it may not continue without some repair or maintenance in due course (Leaman, Stevenson, & Bordass, 2010). This may necessitate user involvement, in identifying the need for repair and making suitable arrangements, for example. The need to monitor and maintain LZC technology is well documented; for example, the Energy Saving Trust (EST, 2006a) states that STHW systems would benefit from annual inspection checks and householders should be provided with maintenance schedules; the Zero Carbon Hub (2012a) highlights the need to adequately maintain MVHR systems to ensure their performance[47]; and Staffell et al. (2010, p.152) note that PV inverters need monitoring to detect instances of tripping due to 'voltage spikes and grid instability'. Within the social housing sector, the need to maintain LZC technology appears generally well-accepted and is typically managed by the asset management department of registered social landlords, as opposed to householders (Kempton, 2014).

Early rectification of faults reduces the time available for these to adversely impact on the technology's socio-technical associations, such as adversely influencing user's perception of the technology (Mlecnik, et al., 2012). Abdel-Wahab et al. (2011), for example, report on the adverse effect that a poorly performing GSHP-based communal heating system had on the onward socio-technical relations between a particular housing association and LZC technology in general. The malfunctioning GSHP was unable to provide the necessary energy services and this had a knock-on effect on the housing association's 'reputation and image' (Abdel-Wahab, Moore, & MacDonald, 2011, p. 320).

Where centralised gas and electricity networks are substituted by, or supplemented with, decentralised LZC technology, what impact does this have on the attention given to maintenance and repair activities? Given the established nature of the gas[48] and electricity networks, a mature maintenance and repair system has evolved to serve the UK domestic market. For example, most householders are aware of the regularity with which gas boilers

[47] Such maintenance includes 'regular cleaning around the ceiling grilles and vacuum cleaning the filters and/or changing them from time to time' (Zero Carbon Hub, 2012a, p. 39).
[48] By 2010, 90% of UK homes had a central heating system and 93% of these were fuelled by natural gas (DECC, 2012e).

should be serviced and many have annual arrangements in place for this, receiving reminders when services are due; that is, there is an established practice in place.

When faults occur to these established networks, it is generally evident as the provision of energy services is either disrupted or diminished[49]. Faults may or may not be accompanied by supportive information from associated devices. For instance, where there is an electrical fault in a particular circuit and that circuit trips, the electrical switchboard will indicate, in the form of a visibly tripped switch, in which circuit the fault lies. Once alert to the need for a repair, householders generally know who to call for assistance, if required (a trusted electrician, for example). If not, householders can readily turn to others for recommendations or to various listings of service providers. In the main, householders are sufficiently enrolled in a socio-technical network that has developed to facilitate the maintenance and repair of the established gas and electricity networks.

For LZC technology, repair and maintenance support networks may, firstly, involve a range of tradespeople and organisations unfamiliar to householders and, secondly, be insufficiently developed. For example, although regular filter changing constitutes a recommended maintenance task for MVHR systems (Yu & Kim, 2012), the absence of 'a market for replacement filters' in the UK implies such maintenance is not commonly undertaken (Zero Carbon Hub, 2012a, p. 6) or potentially provided for. Research supporting this second point indicates that current after-sales support for LZC technology-users is inadequate in the UK (NHBC Foundation, 2012b) and the introduction of contractual guarantees for such service provision is recommended (EST, 2010b). In more mature markets such as Denmark, annual maintenance schemes are typically offered by energy companies for purchasers of heat pumps, with 60% of householders in one survey having such arrangements in place (Gram-Hansen, Christensen, & Petersen, 2012).

Graham & Thrift (2007, p.5) note that the process of fixing faulty systems leads to 'learning, adaptation and improvisation'. A question unaddressed in their account, however, is that of *who* is able to partake in such fixing and thereby benefit potentially from the attendant learning. Householders, for example, may be restricted in their ability to repair devices associated with their energy systems for reasons such as accessibility (as noted for STHW (Caird & Roy, 2008) and MVHR systems (Zero Carbon Hub, 2012a)) and insufficient understanding of how to identify causes and select ameliorative measures.

[49] This illustrates one of Star's defined properties for infrastructure, its visibility 'upon breakdown', highlighting the 'relational nature of infrastructure' (Star, 1999, p. 382).

The speed with which a technological breakdown is investigated and its causes identified is considered by Akrich (1992, p.224) to be a measure of the 'solidity' of the technology's socio-technical network. For LZC technology, there are certain situations where householders may be unaware of a breakdown due to no discernible change in the provision of associated services. Take, for example, a PV installation where the trip switch, generation meter and any displays are located in unfrequented spaces, such as lofts. A power surge can cause the inverter[50] to switch off, or trip, effectively shutting down the system and preventing the generation of renewable electricity (Munzinger, et al., 2006; Jardine, 2006). As access to mains electricity continues, the malfunctioning system remains indiscernible until the generation meter, display or trip switch are visually checked. This state of affairs can continue for some time, as only 40% of householders check their PV display monthly (as found in Munzinger et al.'s (2006) UK study), re-inforcing the need for inverters and displays to be readily available for checking (Munzinger, et al., 2006). Similarly, householders may be unaware of faults or deteriorations in their MVHR system's performance (Hill, 1999) and, because of this, the Zero Carbon Hub (2012a) has recommended that MVHR systems should incorporate indicators that identify the selected operating mode and whether maintenance is required; for the latter, visible and audible indicators are recommended.

The need for diagnostic assistance in identifying malfunctioning LZC technology has also been highlighted by STHW-retrofitters who, in one UK survey, advocated 'a diagnostic system to warn about component failure and to locate leaks in pipes' (Caird & Roy, 2008, p. 345). Even where system displays are accessible, however, this does not necessarily lead people to check them. This is mainly attributed to a poor understanding of what the displayed information means or an inability to properly read the display due to inadequate lighting (Munzinger, et al., 2006). These examples demonstrate the need to give proper consideration to the effectiveness of LZC technology-user interfaces (Boardman, 2007a).

Householders may not know whether periodic maintenance should be undertaken (by themselves or specialist contractors), given that the quality of instructions provided has been both 'inconsistent' and 'inadequate' (NHBC Foundation, 2012b), and any substandard maintenance is expected to contribute to declining efficiences and possible breakdowns (National Housing Federation, 2010).

[50] The inverter converts the generated direct current electricity to alternating current as used within the home.

3.5.2 Faulty installations

The previous discussion on maintenance and repair has not attended to situations where installed technologies are faulty from the outset. Given that LZC technologies are relatively new to mainstream UK developers and regulators, what is the probability of this scenario? It is unlikely that faulty installations would be routinely identified by planning enforcement officers or building control inspectors, in view of limited monitoring and enforcement activities (Rydin, 2010b); a difficulty in detecting performance issues using established inspection techniques (DCLG, 2012a); an insufficient understanding of, and low prioritisation given to, the energy performance of new buildings (Adeyeye, Osmani, & Brown, 2007; Fischer & Guy, 2009 & 2011; Pickvance, 2009; Pan & Garmston, 2012a & 2012b; NHBC Foundation, 2012d); and competition for developer clients between local authority inspectors and their private counterparts, which may lead to greater leniency (Hawkesworth & Imrie, 2009; Lowe & Oreszczyn, 2008; DCLG, 2012a).

The need for more thorough commissioning of LZC technology to improve detection rates for incorrectly installed and underperfroming installations is a point raised by Boardman (2007b), and demonstrated by Bell et al.'s (2010) research on STHW systems. The commissioning process is key to optimising the set-up for MVHR systems (Zero Carbon Hub, 2012a) and ASHPs (EST, 2010b), for example, but evidence suggests that commissioning standards are not being adhered to (Zero Carbon Hub, 2012a). In response to concerns raised by studies undertaken, DCLG (2012a, p.47) is advocating that the Government, industry and the building control bodies work towards ensuring 'that regulatory requirements for zero carbon are verifiable in the course of building control inspections'.

The evidence for poorly installed LZC technology is increasing, with causes attributed to flawed designs, faulty installations, inadequate commissioning, poor workmanship and inadequate communication between trades (NHBC Foundation, 2011a; Zero Carbon Hub, 2012a; Munzinger, et al., 2006). A survey of 39 retrofitted STHW systems, for example, found that 80% exhibited faults, with leaks and faulty parts noted (Caird & Roy, 2008). Similarly, in a field trial of mainly retrofitted heat pumps (comprised of 29 ASHPs and 54 GSHPS), many faulty installations were observed and the involvement of a variety of contractors (such as, plumbers, electricians and heat pump installers) was identified as an issue, in terms of allocating overall responsibility for the quality of installations (EST, 2010b).

The reliability of domestic LZC technology, the efficacy of maintenance and repair support systems (Walker, 2008a), and the extent to which LZC technology is maintained and repaired are matters still to be determined and this research contributes to current knowledge in this area.

Research question: What is the prevalence and cause of faulty LZC technology and how do these faulty installations come to light? (→ Section 8.2)

Research question: To what extent are LZC technologies maintained, and what are the underlying reasons for this? (→ Section 8.3)

Research question: What are the wider benefits of maintenance processes? (→ Section 8.3)

3.6 Shaping of users

3.6.1 Agency

When, and if, an individual learns that to maximise gains from a LZC technology, they will need to amend their interactions with it or amend how certain connected activities are undertaken, they have a choice. They can make informed changes to improve its performance or they can continue as before and accept an under-performing technology. As Georg (1999, p.455) notes:

> 'Not all citizens have the time or are willing to take the time to reorganise the routines of everyday life.'

Whether householders instigate any significant change due to a new technological association will, in part, be influenced by the 'elasticity' (Wilson & Dowlatabadi, 2007, p. 191) or 'room for manuevering' (Oudshoorn & Pinch, 2005, p. 6) inherent within their daily schedules, as determined by the presence of constraining factors. Of course, certain changes to routines may be imposed by the technology. Take, for example, householders who typically dry clothes on radiators; the introduction of a combined ASHP and radiator system would necessitate a procedural adjustment as radiator temperatures become too low[51] for effective drying to occur.

[51] As explained in Section 7.3.

As LZC technology has the potential to reduce the environmental impact of domestic activities[52], it provides householders with an opportunity to assess the 'limitations of their 'own green-ness'' (Hobson, 2006a, p. 329), noting the constraints on change that may be imposed by other household members (Reimer & Leslie, 2004). Where it is the potential economic savings to be realised by instigating change that most appeals, householders may weigh up the notional costs of change, in terms of the time and effort required and the disruption it may cause.

A new association between a householder and a technology will change the circumstances of each (Law & Callon, 1992) and has the potential to modify the householder's identity, as this is 'forged in and through relations' (Massey, 2004, p. 5); alternatively phrased, 'new linkages distinguish the entities in new ways' (Murdoch, 1997, p. 331). Where technologies instigate changes to householders' actions and views, about themselves and the wider world (Oudshoorn et al, 2004), they can be considered to have enabled or promoted a re-shaping of these individuals.

At this point, it is useful to introduce the concept of agency; an entity has agency if it demonstrates an ability 'to be the source and originator of acts' (Wilhite, 2007, p. 24). At the core of ANT is the concept that non-human, as well as human, entities can exhibit agency and those that do are referred to as 'actants' (Akrich & Latour, 1992, p. 259). Policy-makers (via designers and developers) have delegated onto technologies (Paredis, 2011) certain responsibilities for delivering reductions in CO_2 emissions and they have been designed in theory with competences to do so. The effectiveness with which they function will depend, to varying degrees, on the ability of the LZC technology (and any associated entities bearing the distributed inscription) to enrol the householders into behaving in certain ways. To the degree that householders change their actions (and views) as a result of their association with LZC technology, it has exhibited agency.

LZC technology can also be viewed as exhibiting a form of agency when householders specifically select their home because of the technology's presence. Most people will have no prior interactions with technologies such as MVHR systems and Lovell (2005, p.819) argues that this may hinder the rate at which 'more active consumer demand' for low energy housing develops. Lovell (2005) held focus group interviews with 14 residents of homes considerably more energy-efficient than that required by the Building Regulations at the time, incorporating

[52] In CO_2 emission terms.

MVHR and STHW technologies. Half identified sustainability as the main reason for purchasing their home, whilst the rest cited location as the main factor (Lovell, 2005). This study, then, highlighted that the dwelling's sustainability (if not the LZC technology specifically) had exhibited a degree of agency in attracting prospective occupants.

This thesis focuses on households occupying new homes fitted with LZC technology. Apart from a few exceptions, these dwellings have no other notable sustainable features beyond that required by the Building Regulations and they are not eco-homes or homes built to a specified level under the CSH. To what degree, then, does householders' knowledge of the LZC technology in such mainstream new housing influence their home selection process? A study of five UK households (NHBC Foundation, 2012d) noted that they were typically unaware of the LZC technology before purchasing their home and most did not consider environmental performance as a key factor in their home's selection. Apart from this and two other small-scale studies (Ghanem, 2008; NHBC Foundation, 2013b), the influence of LZC technology on the home selection process remains an under-researched topic.

Research question: To what degree are LZC technologies actively appropriated in new dwellings? (→ Section 6.2)

Agency can be further conceptualised as either intended or unintended, as viewed from the designers' perspective. When householders subscribe to those actions intended by designers, the LZC technology has successfully enacted the intended (or delegated (Akrich & Latour, 1992; Harty, 2010)) agency. Where householders' actions, made in response to their association with the technology, are outside the set of reactions intended by designers and policy-makers (Wilhite, 2007), the technology has enacted an unintended agency. For example, where a householder's views become re-shaped by their interaction with LZC technology, such changes open up the potential for affecting their behaviour in other settings unrelated to the technology. Such unintended agency[53] may be categorised as positive or negative in relation to efforts to reduce CO_2 emissions.

I have mentioned scenarios where envisaged CO_2 reductions may not transpire; due to misuse, indifference to, or rejection of LZC technology, for example. Another scenario is where technologies are made use of but, in the process, users' expectations of energy service provision changes. Such a phenomenon was initially observed in studies involving installations

[53] As drawn attention to by Davies & Oreszczyn (2012) in their review of unintended consequences associated with decarbonising UK housing.

of energy efficient technologies, which were found to potentially lead to increases in demand for energy consuming services, thereby reducing the potential energy (and cost) savings that could be achieved (Sorrell, 2009). This phenomenon is termed a 'rebound effect' (Sorrell, 2009, p. 1456; Jenkins, Nordhaus, & Shellenberger, 2011). Although a worthwhile area of study, this thesis does not extend to a consideration of any rebound effects associated with LZC technology. However, Appendix 1 includes a discussion of this topic.

In terms of the LZC technology-householder association, does this itself act as a change agent for others? To what extent does installed technology within one household cause neighbours, friends and family to install such technology (through users acting as 'peer-to-peer 'experience' experts' (Mlecnik, et al., 2012, p. 471))? In a survey of 39 STHW-retrofitters, three quarters identified one of the prompts for this retrofit as being the observation of such technology in their neighbourhood or amongst friends and family (Caird & Roy, 2008). Similarly, Wilson & Dowlatabadi (2007, p.180) report on studies where early PV-users acted as effective change agents to others and 'supported diffusion more effectively than detailed technical information'[54]. Given the strength of this factor, Caird & Roy (2008) advocate a better understanding of the communication pathways at play.

Research question: To what extent do new home occupants recommend their LZC technology to others and have these others proceeded to install technology? (→ Section 9.3)

3.6.2 Structuring the temporal order of activities

According to Shove (2003), one element typically excluded from user-technology studies is a consideration of how technologies influence, or script, users' activities in time and one way technology may exhibit agency pertains to changes they can make to the 'temporal ordering' of activities (Shove & Walker, 2010, p. 471), where schedules become restructured (Shove, 2003). The ability of technology to 'structure the temporal order of interactions and activity' (Preda, 1999, p. 355) within their setting, in order to optimise their performance and utilisation, will be of varying relevance for different LZC technologies. Such temporal inscriptions are particularly pertinent for STHW systems. In order to optimise the utilisation of solar-heated water, and to minimise reliance on conventional heating systems, users may need

[54] Mahapatra & Gustavsson (2010) have proposed that householder's attitudes towards their LZC technology may influence the extent to which they recommend it to others.

to alter the timing of hot water-using activities. Where solar radiation is significant but sufficiently heated water for, say, bathing purposes only becomes available in the afternoon, a user intent on relying solely on solar-heated water would need to mould their bathing activities around this temporally-determined availability (though this dependency would be reduced where heated water can be effectively stored in sufficient quantity until the next day, which will effectively 'delineate supply and demand' (Staffell, et al., 2010, p. 144)). Given daily and seasonal variability in solar radiation, the idealised user (defined here as one who maximises CO_2 reductions through capitalising on solar-heated water usage) would exhibit a high awareness of weather variability (or close attendance to feedback devices), a sufficient understanding of how the technology works and a willingness and ability to alter the temporal ordering of activities on an on-going basis.

The ability of STHW systems to temporally order users' activities relates not just to those activities which directly consume hot water; it also relies on the timely flexibility of those activities which can only occur subsequent to the consumption of hot water, that is, knock-on activities or 'interrelated practices' (Southerton, 2006, p. 435). Hand et al. (2005), for example, draw attention to the role that showering plays in getting ready in the morning or in preparing to go out. Additionally, temporal re-ordering relies on the willingness of users to alter the timing of other activities that are dislodged from their customary time slots by the solar-driven and fluid reconfiguration of daily activities. In reality, to what extent can STHW systems be considered 'as *nodes* around which other elements […] are temporally centred' and to what extent, then, can such systems be said to demonstrate 'agency in temporal affairs' (Preda, 1999, p. 355)? In a survey of active and passive LZC technology adopters, evidence of load shifting[55] was found in certain UK households who bathed or showered at times when solar-heated water had become available (Dobbyn & Thomas, 2005). In a further UK survey of 39 STHW retrofitters, 47% tried to make use of solar-heated water by deferring the timing of activities such as showering (Caird & Roy, 2008).

The need to pay attention to the UK weather is also required when striving to maximise savings from PV installations (Nye, Whitmarsh, & Foxon, 2010). Typically, a household's daily electrical demand profile differs from the PV-generation profile (Bahaj & James, 2007) but, due to variance between generation, export and import tariffs, it is financially advantageous to maximise the use of electricity at the time it is generated (CSE, 2012; McManus, Gaterell, &

[55] Load shifting occurs when energy-consuming activities are timed to tie in with the variable generation of renewable energy through the day.

Coates, 2010). Research into behavioural responses to PV systems cites evidence of load shifting occurring in some studies (Keirstead, 2007; Abdel-Wahab, Moore, & MacDonald, 2011; Monahan, 2013[56]) but very little in others (Bahaj & James, 2007). Abdel-Wahab et al. (2011) comment that the ease with which residents are able to alter their habits varies. This finding is supported by a survey of 229 PV households (a mix of new build and retrofits) in which 24% of users stated that they had instigated some degree of load shifting, whereby washing appliances had been re-scheduled to run during the day to make use of PV-generated electricity (Munzinger et al, 2006). Reasons for why others were not load shifting were suggested as being potentially attributable to people being out during the day, a lack of timer-fitted appliances, and a lack of understanding as to the benefits of using electrical devices to coincide with the generation of PV electricity (Munzinger, et al., 2006, p.72). Research by Hargreaves et al. (2010, p. 6117) on smart metering[57] also suggests that households may require 'significant financial incentives'[58] before load shifting would be contemplated and many householders noted that their ability to control the timing of activities was restricted. The performance of solar-based LZC technology is particularly influenced by the seasons. For those that align their activities (to varying degrees) with daily outputs from STHW and PV systems, the seasons will impose a necessary periodic readjustment of this alignment.

Research question: To what degree does LZC technology exhibit agency in everyday temporal affairs? (→ Section 7.4)

Research question: To what extent does feedback from LZC technology engage householders and shape actions? (→ Sections 7.4)

3.7 Assisting & learning from users

As the building industry moves incrementally towards zero-carbon homes (Section 2.3), the extent to which set standards will actually be achieved is uncertain as evidence already suggests that new homes may miss regulatory CO_2 emission targets (DCLG, 2012a; NHBC Foundation, 2012c; Banfill & Peacock, 2007; Pan & Garmston, 2012b; Bell, et al., 2010) by a

[56] In Monahan's (2013) research, one PV-user had purchased timers for appliances to facilitate load shifting.
[57] Which can be considered as 'mediating technologies' (Furlong, 2010, p. 463) designed to increase the visibility of energy consumption.
[58] With regards to the role of financial incentives, Nye et al. (2010) suggest that variable electricity tariffs designed to shift consumption away from peak periods (introduced in parallel to smart meters) could assist with redistributing temporal patterns of consumption.

‘wide margin’, a situation described as a ‘CO_2 performance gap’ (NHBC Foundation, 2012a, p. iii) or energy performance gap (Zero Carbon Hub, 2014). The NHBC Foundation (2012a) focuses on addressing this disparity between as-designed and actual performance by considering issues such as how CO_2 predictions are calculated; whether there is a mismatch between available construction skills and those required by advancing house designs (see also Jagger, Foxon, & Gouldson (2013)); and whether post-construction testing and checking is sufficient. In addressing the modelling methodology currently used to predict a dwelling’s CO_2 emissions, DECC (2011b) indicates it is to be aligned more closely with the potential of LZC technology. The Government has also consulted on the introduction of a new quality assurance process for the house-building sector to address the CO_2 performance gap (DCLG, 2012b) but some representatives from the building control sector argue instead for strengthening inspection work and post-construction testing (DCLG, 2012b).

Learning from users as to how and why they interact with technology as they do provides an opportunity for policy-makers and developers/designers to appraise how they might intervene to improve the design, installation and use of these technologies (NHBC Foundation, 2011b; Janda, 2011). Rohracher’s (2003) research pertaining to MVHR systems in Austria, however, illustrates that such learning processes are limited and disorderly, unassisted by the nature of the relevant institutions and availability of communication pathways. In posing the question of how policy could be used to promote learning processes between users, producers and other relevant players, Rohracher’s (2003, p. 189) research suggests:

> ‘improving the institutional framework to support learning processes[59] or directly intervening (or participating) in the networks of actors to induce further learning processes.’

This view is supported by research undertaken on social housing in the UK (EST, 2011a; Abdel-Wahab, Moore, & MacDonald, 2011; Kirwan, 2007), where pertinent success factors were identified as ‘education, user training programmes and on-going support’ (EST, 2011a, p.20). These factors were particularly key where changes to occupants’ behaviour were needed to optimise systems, such as understanding the need to switch immersion heaters off unless required when STHW systems were installed (EST, 2011a). In this study, the need for ‘simple and familiar’ controls was seen as particularly important for what they considered to be ‘more vulnerable tenants’ (EST, 2011a, p. 20). To assist with enhancing the performance of LZC technology, the National Housing Federation (2010, p.6) has published guidance whose ‘key

[59] One option for supporting learning processes could involve technology users ‘defining further design requirements’ that could be incorporated into future installations (Rohracher, 2003, p. 189).

lesson' is that these technologies cannot be fitted and forgotten but require 'ongoing monitoring, education and advice' and 'changes to behaviour' to realise CO_2 reductions.

This recommendation concurs with other research where the provision of improved advice to users was considered key (EST, 2011b; Dobbyn & Thomas, 2005; NHBC Foundation, 2011b), though the NHBC Foundation (2012c) reports on unpublished research suggesting some householders may not refer to the manuals provided at all, leading to a potentially increased probability that technologies will not be optimised. This has indeed been observed by Monahan (2013) in her study of 15 new social housing units (13 of which had LZC technologies), where only 36% of households had referred to the tenants pack provided. The NHBC Foundation (2012c) consequently calls for additional research into whether manuals are used and in what ways they can be enhanced with respect to content, presentation and timing of provision.

Research question: What are householders' perceptions of the written instructions provided for LZC technology? (→ Section 6.3)

Research question: Which sources of information do householders refer to in order to improve their understanding of LZC technology? (→ Section 7.2)

The National Housing Federation (2010) has gone further in recommending that housing associations undertake post-occupancy evaluations (POEs) for up to two years to track and help optimise LZC technology performance. Beyond troubleshooting, they advocate obtaining feedback on residents' experiences, covering issues such as their 'understanding of controls, thermal comfort levels, noise levels, general perceptions and overall satisfaction' (National Housing Federation, 2010, p. 16). This wide interpretation of POEs is advocated by certain researchers who variously contend that, in addition to assessing how a building is performing, it is also important to establish 'how the household performs' (Vale & Vale, 2010, p. 586); the effectiveness of the induction process (Stevenson & Rijal, 2010); the usability of technology-user interfaces (Stevenson & Rijal, 2010; Stevenson, Carmona-Andreu, & Hancock, 2013); the impact of behaviours on energy consumption (Gill, et al., 2010); and to highlight the reasons underlying householders' behaviour in relation to energy consumption (Stevenson & Leaman, 2010).

Research question: What verbal instruction on LZC technology is provided on moving in? (→ Section 6.4)

Currently, a requirement for POE does not form part of the UK Government's drive to deliver low carbon housing and extensive information on the in-use energy performance of new dwellings is lacking (Stevenson & Leaman, 2010). Without effective feedback to policy-makers and enforcers, there 'is no continued duty of care or responsibility beyond the planning application and building permit process', as commented on by an interviewee in Moore & Rydin's (2008, p.251) research on sustainable construction. Feedback to architects, designers and developers is also key if deficiencies in design and hand-over procedures are to be rectified (Stevenson & Rijal, 2010; NHBC Foundation, 2012c). In DCLG's (2012) consultation on changes to the Building Regulations, the development of a quality assurance standard to improve design and construction standards is discussed, and it is suggested that integral to such a standard would be the introduction by house-builders of feedback mechanisms to promote improvements in performance. The extent to which developers of mainstream new housing currently seek feedback on LZC technology is unknown.

Research question: Has any on-going communication been received or feedback sought in relation to the LZC installation? (→ Section 8.3.1)

3.8 Conclusions

As examined in this chapter, published research on LZC technology-user associations is based mainly either on studies of retrofitted systems within private and social sector housing or on installations within specific new developments built to high environmental and/or nearly zero-energy standards. This new housing is untypical of new mainstream housing equipped with LZC technology.

Absent from the research literature are any studies founded on LZC technology-user associations as observed across the geographical area of a local authority, and one in which most new dwellings built over recent years have had LZC technology installed to meet a LZC energy policy. The undertaking of such research has several advantages. Firstly, it provides an insight into what LZC technology developers select to comply with Merton Rule-type policies[60]. It would consequently provide an indication of which LZC technologies will be selected by developers to comply with increasingly stringent energy performance standards as specified by

[60] There has been some research into the range of LZC technology types different developers select from to comply with the CSH, but this did not obtain data on the number of installations of each type installed (Lees & Sexton, 2014).

the Building Regulations. Secondly, by selecting a geographical area specific to one local authority, the research enables a targeted assessment to be made of the outcomes from the implementation of a specific policy. Lastly, by encompassing all new developments built since the introduction of the relevant policy within the research, a more comprehensive, geographically-grounded piece of research can be conducted, which seeks to include all sizes and types of developments, neighbourhoods, occupants and technologies.

Through the discussion in this chapter, certain research questions have emerged as posing worthwhile areas of research that can contribute to the extant academic literature. The phrasing and derivation of some of these research questions are derived in part from the technology studies version of domestication theory, as discussed within Chapter 4. A summary of the research questions is presented at the end of Chapter 4.

Chapter 4: Theoretical & methodological approaches

4.1 Introduction

In Chapter 3, I reviewed the academic research which has contributed to current understandings of LZC technology-householder associations. In presenting this review, I adopted a socio-technical perspective as two strands of this perspective, namely domestication theory and ANT, have guided the research. Some of the pertinent concepts pertaining to these approaches have therefore been discussed previously.

In Section 4.2, I start by providing a more in-depth discussion of domestication theory and proceed to provide an account of the technology studies version of domestication, which incorporates aspects of ANT. I then demonstrate how this version provides a useful framework for studying the socio-technical associations between householders, LZC technology and other pertinent entities, and how it has informed the derivation of certain research questions.

The aim of the research was to use the technology studies version of domestication theory in an interventionist way (Vikkelsø, 2007). The approach was employed to generate a description (and explanation) of the state of LZC technology-user associations within the selected population. The aim of the research was then to use these findings to guide the formulation of interventionist strategies aimed at improving the CO_2 reduction potential of LZC technology-householder associations within the selected population; specifically, the last research phase was to constitute a form of action research, as discussed in Section 4.3.

Section 4.4 concludes the chapter with a summary of the research questions distilled from the discussions within Chapters 3 and 4.

4.2 Technology studies version of domestication

4.2.1 Introduction

Domestication theory (introduced in Chapter 3) emanated from information and communication technology (ICT) studies and has been mainly employed to study the 'acceptance, rejection and use' (Berker, et al., 2006, p. 1) of technologies such as television, computers and the internet (Harwood, 2011). It has also been used more widely within STS research (Berker, et al., 2006; Carter, Green, & Thorogood, 2013), in research pertaining to the appropriation of knowledge (Ryghaug, Sørensen, & Næss, 2011), the domestication of public spaces (Koch & Latham, 2013), and the study of smart energy monitors (Hargreaves, Nye, & Burgess, 2013) and LZC technology by human geographers (Ghanem, 2008; Wrapson & Devine-Wright, 2014)[61]. Building on the 'micro-sociological' (Silverstone, 1993, p. 227) domestication approach, Sørensen (2006) incorporates aspects of ANT within his studies of how technology-user associations develop.

In this section, I discuss some of the pertinent tenets of domestication theory. I then present Sørensen's (2006) version of this approach, followed by an explanation of how applying this version can elicit insights into how LZC technology-user associations develop.

4.2.2 Domestication theory

Origins, concepts and applications

In the early 1990s, domestication theory focused on socio-technical changes pertaining to ICT that were occurring at the individual and household level (Silverstone & Haddon, 1996). It theorised how these technologies, actively purchased for the home, came to be domesticated, giving attention to 'the dispersed and often dissonant micro-developments' occurring (Bakardjieva, 2006, p. 64). The approach aims to elucidate how technologies become embedded in everyday lives through their integration 'into the structures, daily routines and values of users' (Berker, et al., 2006, p. 2), attending to how technology is functionally and symbolically enrolled into homely activities.

Domestication theory acknowledges that in the process of enrolling a new technology into a particular setting, both the technology and the user(s) may change (Silverstone, 2006; Hynes & Rommes, 2006; Silverstone, Hirsch, & Morley, 1992):

> 'We are also consumed by the artefacts when they gain our attention and have us react to them and become occupied by their abilities, functions and forms.' (Lie & Sørensen, 1996, p. 8)

This process of change is recognised as being potentially on-going (Aune, 1996) and non-linear (Lie & Sørensen, 1996). As noted in Section 3.2.1, domestication theory is viewed as employing a more user-centred perspective on technology than ANT (Sørensen, Aune, & Hatling, 2000).

[61] Others have combined aspects of domestication theory with ideas from practice theory to help understand how new technologies bring about changes in consumer practices (Gram-Hanssen, 2011; McMeekin & Southerton, 2012).

Within ANT, the point of reference is the designers' intention for how the technology should be used (Akrich & Latour, 1992). With domestication, the point of reference is the user of the technology and their relationship with it (Silverstone & Haddon, 1996). In some sense, domestication refers to the sequential phases of a process, or a series of trials (Section 3.4), through which the technology-user association develops. This process, viewed from the user's perspective, does not need necessarily to incorporate any direct reference to what the designers' intentions were for the technology (Laegran, 2005).

Work to domesticate a new technology is considered to operate at up to three levels:

> 'Domestication processes include symbolic work, in which people create symbolic meanings of artifacts and adopt or transform the meanings inscribed in the technology; practical work, in which users develop a pattern of use to integrate artifacts into their daily routines; and cognitive work, which includes learning about artifacts.' (Oudshoorn & Pinch, 2005, p. 14)

In addition to operating at these functional, symbolic and cognitive levels, the theory conceptualises the enrolment process as involving four notional components: appropriation, objectification, incorporation and conversion (Silverstone, 2006; Lie & Sørensen, 1996), which make the process of domestication 'more analytically tangible' (Aune, 1996, p. 94). These components are not regarded as rigid, sequential stages of a linear process, but as overlapping, contributory processes that provide a framework for analysing and representing the ways in which householders and technologies interact. Not all four stages may be passed through (Hynes & Rommes, 2006) and, once domesticated, technologies may become de-domesticated or re-domesticated at later times. Additional aspects to domestication theory include moral economy[62] and double articulation[63] (Silverstone, 2006; Silverstone, Hirsch, & Morley, 1992); these aspects apply more to the specific nature of ICT and the content of the communications and messages that they introduce into the home, and are deemed somewhat less applicable to this research on LZC technology. Domestication's four components are now outlined in turn.

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[62] For Ward (2006, p. 148), the household's moral economy refers to the process whereby: 'commodities are appropriated from the 'formal' economy and brought into the domestic sphere, where they are inscribed with private meanings and transformed into acceptable symbolic objects, which construct and articulate the values of the home.' The concept is further explained by Silverstone et al. (1992).

[63] The concept of double articulation refers to certain technologies that represent objects and media. These technologies, such as televisions, are consumed in two ways: both as objects and through the content of the television programmes they deliver into the home (Silverstone, Hirsch, & Morley, 1992).

Appropriation of technology, or a less material entity such as media content, occurs at the point at which it is bought (Silverstone, Hirsch, & Morley, 1992) or otherwise acquired (Laegran, 2005) and taken ownership of. In Silverstone's (2006, p.233/234) account, commodification 'prepares the ground for the initial appropriation of a new technology' and this early stage of domestication incorporates aspects of the technology's design and marketing, and also relevant aspects of public policy that might relate to its acquisition. The meaning attached to a technology may change as it transfers from the public realm to the specifics of any particular private sphere, and its appropriation may be 'central to an individual's or a household's efforts at self-creation' (Silverstone, Hirsch, & Morley, 1992, p. 22).

Objectification relates to how the technology is located in terms of the 'material, social and cultural spaces of the home' (Silverstone, 2006, p. 235). For example, for a moveable technology, objectification encompasses where it is placed or displayed. Objectification also encompasses the placement of technology within thought processes (or 'mental space' (Laegran, 2005, p. 82)) and its positioning within intra-household relationships, including whether it brings changes to prevailing gendered practices. Silverstone, Hirsch, & Morley (1992, 23) assert that:

> 'An understanding of the dynamics of objectification in the household will also throw into strong relief the pattern of spatial differentiation (private, shared, contested; adult, child; male, female, etc.) that provides the basis for the geography of the home.'

Silverstone, Hirsch, & Morley (1992) also explore the concept of objectification for less material entities, such as television programmes, and highlight how the content of these become objectified through intra-household discussions.

Incorporation pertains to how new technologies (and other material/non-material entities) and their associated routines are inserted into 'the temporal patterns of domestic life' (Silverstone, 2006, p. 235). Hynes & Rommes (2006, p.129) state that 'in order to become functional, a technology has to find a place in the routines of daily life' where 'the main focus is a temporal one (when it is used and for how long).' Silverstone, Hirsch, & Morley (1992) also view incorporation as involving articulations of both gender and age in determining who uses, or is excluded from using, the technology. This process of incorporation, for example, reinforces 'a family's gendered culture of technology' (Silverstone, Hirsch, & Morley, 1992, p. 25).

Together, the ways in which technologies are objectified and incorporated (which overlap in their explanatory remits) into a given household contributes to the on-going processes which forge the identities of, and lead to the differentiation between, household members; it also contributes to the identification and differentiation between households (Silverstone, Hirsch, & Morley, 1992).

Conversion, the remaining component of domestication, involves connecting with others outside the home in relation to the appropriated technology, where discussions involve 'the sharing of the pride of ownership, as well as its frustrations' (Silverstone, 2006, p. 234). Hereby, the personal, symbolic meanings assigned to the technology and information relating to how it performs, for example, are communicated to family, neighbours and acquaintances; in so doing, users serve as 'warm experts' on the technology to others (Bakardjieva, 2006, p. 67). Through this conversion, the technology and its use contributes to the shaping of relations between users and others beyond the home (Oudshoorn & Pinch, 2005). Householders, for example, may employ technologies as 'tools for making status claims and for expressing a specific lifestyle' (Oudshoorn & Pinch, 2005, p. 15).

The airing of personal meanings assigned to technology also contributes to the on-going development of the public meanings attached to them (Hynes & Rommes, 2006). For example, Hynes & Rommes (2006, p.128) note how:

> 'conversion is of importance in explaining how potential new users gain their representations of computers, once again starting the domestication process for new users.'

Peine & Herrmann (2012, p.1500) consider that:

> 'Through conversion the local work of users contributes to the generalization and stabilization of a technology's identity in the public sphere as well. In principle, therefore, domestication describes a collective and cumulative learning process ...'

Without this conversion, the processes of appropriation, objectification and incorporation and their outcomes remain hidden within the confines of the home and do not contribute, for instance, to the development of domestication trajectories in other homes. In such cases, domestication processes have no 'public consequence' (Silverstone, Hirsch, & Morley, 1992, p. 26).

In critiquing domestication theory, Mackay (2008, p.378) is concerned at the 'breadth of issues' addressed and the 'broad-ranging and flexible' ways in which it is utilised, suggesting this inconsistency may detract from the concept's usefulness. From reading various research accounts, I note that the emphasis on the four domestication components may vary with the setting under study, but the usefulness of the concept in generating insights into the development and variety of technology-user interactions is drawn attention to by researchers (see Carter, Green, & Thorogood (2013), for example), countering this criticism. Additionally, Mackay (2008, p.379) asks 'where is the technology that it is claimed is being shaped?' Here, he appears to expect accounts of how technological designs have been influenced by users. This sort of historical research would need to span extended periods of time and is not the focus of much of what is published. Instead, it is at the micro-sociological, user-specific level that accounts of technological shaping are given, as with this research. Here, Mackay's (2008) criticisms would appear misplaced.

According to Hynes & Rommes (2006, p. 125):

> 'Little attention has been paid to domestication processes that are problematic, reversed, stopped altogether, or influenced by factors such as the availability of resources …'

They conclude that the domestication concept 'ignores the diversity of users' (Hynes & Rommes, 2006, p. 125), but this would seem to relate to how the concept is applied and how those that are researched are selected. In this research, I specifically attend to the diversity of users and what this means for the processes of domestication. For some householders, the domestication of LZC technology may prove problematic (where, for example, they object to the technology) and attention will be paid to the factors that contribute to any such state of affairs.

4.2.3 Technology studies version of domestication

Certain researchers have developed a version of domestication theory more aligned with ANT's sensibilities (Lie & Sørensen, 1996; Sørensen, 2006; Sørensen, 2004), termed the 'technology studies version' of domestication (Berker, et al., 2006, p.10). Herein, technology is not regarded as a mere artefact but as being comprised of a set of socio-technical relations and, through the domestication process, the socio-technical relations of the user and the technology alter (Silverstone, 2006; Sørensen, 2004).

Given the spatially localised nature of many domestication studies, the concept of micro-networks or socio-technical ensembles (Sørensen, Aune, & Hatling, 2000) has been introduced into the technology studies version of domestication[64]. At the same time, this approach extends the domestication process beyond the household to consider the extent to which there is an institutional framework to 'support and regulate' the technology's use (Sørensen, 2006, p. 47). In this way, the wider socio-technical network relating to the technology is encompassed within any analysis to the extent that this wider network influences the technology's domestication[65].

In analysing the modes of use for a technology, the technology studies version of domestication incorporates ANT concepts such as scripts[66] and associations. With the latter, Sørensen (2006, p.47) regards domestication 'as the process through which an artefact becomes associated with practices, meanings, people and other artefacts'; in other words, how the technology's socio-technical network comes to be. The domestication of technology is also interpreted through the lens of ANT as the ways in which users come to read, understand and act upon the technology's 'script' (Akrich & Latour, 1992, p. 259) or 'programme of action' (Latour, 1992, p. 233). Other concepts such as immutable mobiles[67] (Law & Singleton, 2005; Latour, 1986), 'black boxes'[68] (Latour, 1994, p. 36) and 'anti-programs'[69] (Akrich & Latour, 1992, p. 261) are also useful when analysing and describing the ways in which, and the extent to which, technologies become domesticated.

The preceeding paragraphs discuss the contributions ANT makes to domestication theory. Domestication theory also contributes to ANT in that it can provide, firstly, a temporal framework for studying the development of associations between specific users and specific technologies (Sørensen, 2006; Sørensen, 2004), providing a 'microhistory' (Brosveet & Sørensen, 2000, p. 264) of an association. Domestication theory also provides a framework for thinking through how and why these associations develop over time at the symbolic, functional and cognitive levels, as the technologies become progressively domesticated (or re/de-domesticated).

[64] Although ANT is often applied to the study of extensive networks with a multitude of enrolled entities (such as Lepawsky & Mather's (2011) research into the global circulation of electronic waste), ANT is also used in the study of more limited networks and even single links (such as Sheehan's (2011) work on the relationship between researchers and research participants).
[65] Brosveet & Sørensen (2000), for example, in their application of the technology studies version of domestication, extended their analysis of multimedia adoption up to the national level in Norway.
[66] Discussed in Section 3.4.1.
[67] Discussed in Section 3.4.2.
[68] Discussed in Section 3.4.2.
[69] Discussed in Section 3.4.5.

Sørensen (2006, p.56) describes how the ways in which an individual (or household) domesticates a technology will be 'disciplined through expectations and norms' and will contribute (through the conversion process) to formulating the expectations and norms that others then are disciplined by, thus helping to shape future domestication trajectories. With a newly introduced technology, users' expectations of it may be misplaced and norms pertaining to it may as yet be undeveloped; in such undisciplined situations, a wide range of domestication trajectories might unfold (Sørensen, Aune, & Hatling, 2000). The range of domestication trajectories pertaining to LZC technology in new homes is an issue I attend to in this research.

4.2.4 Application of the technology studies version of domestication theory

Considering the four domestication components in turn, the application of the technology studies version of domestication theory to this research is discussed.

***Appropriation of LZC technology**:* New home occupants are generally not involved in the selection of pre-installed LZC technology. Thus, these households have not selected such technology as singular commodities; instead, they form part of the home which can be viewed as a large-scale commodity which the households come to possess and inhabit. The degree to which the incumbent LZC technology represented a desirable feature, and the degree to which it can therefore be viewed as actively contributing to the home's marketability (as discussed in Section 3.6.1), is a research question addressed by this study:

Research question: To what degree are LZC technologies actively appropriated in new dwellings? (→ Section 6.2)

The degree of appropriation will be influenced by the extent to which information on these technologies formed part of the marketing material and sales pitch from the developer, landlord or agent, and this is explored. It should be remembered that the developers in this research have typically installed LZC technology to comply with the local planning policy rather than to provide more sustainable housing by choice. The extent to which the technology is drawn attention to may reflect the degree to which there is confidence that it adds to, rather than detracts from, the home's appeal.

Objectification of LZC technology: With regards to LZC technology in new homes, the physical aspect of objectification is restricted by the fixed positioning of the technology and its associated devices, as determined by the dwelling's designers. The ways in which the technology has been physically embedded, however, may influence how it comes to be domesticated (see Section 3.4.1), and I will evaluate this for different technology types:

Research question: How are users configured by the design, placement and settings of LZC technology (→ Section 7.3)

The ways in which technology is positioned with respect to intra-household relationships is also questioned. Hynes & Rommes (2006, p.128) advocate attending to who in the household makes the decision to domesticate a technology, 'rather than studying the family as a unit and ignoring the different positions of various family members.' Within this research, it is developers who have selected and installed LZC technology (within the confines set by local policy-makers). However, the fuller processes of domestication may throw up differences between household members and the summing up of such differences across a range of households may highlight patterns of gendered or other differentiation.

Lie & Sørensen (1996, p.21/21) note that gender issues are often presented, or argued, in non-gender terms, such as '"familiar/non-familiar", "competent/non-competent", and "interested/uninterested"'. Given that these technologies will typically have been previously untested within each household, and therefore not previously 'assigned gender characteristics' (Sætnan, 1996, p. 37), the elements of this gendering process may yet be discernible and emergent. The ways in which the domestication of these technologies is re-enforcing or shifting 'gendered identities' (Lie, 1996, p. 205; Oudshoorn & Pinch, 2005) is an under-researched area that this thesis contributes to:

Research question: Do LZC technologies slot into existing gendered patterns of everyday life? (→ Section 9.2)

Just as the content of media technologies can be seen to be comprised of the information, messages and entertainment that they deliver, so the content of LZC technology could possibly be viewed as the renewable or low carbon space heating, hot water and/or electricity that it generates and makes available to occupants. I consider the extent to which LZC technology and its content are objectified through intra-household discussions in Section 9.2.

The objectification of technology is also constituted by the meanings ascribed to it and the research considers the differences in meaning ascribed to LZC technology (see Section 3.3):

Research question: What symbolic meanings do new home occupants attach to LZC technology, and do these ascribed meanings affect how the technology is used? (→ Section 9.4)

Incorporation of LZC technology: The functionality and benefits of LZC technology is influenced, to varying degrees depending on the technology type, by how it is incorporated into daily and periodic routines, as discussed in Chapter 3. Such incorporation may, for example, involve changes to the timing of certain activities and the monitoring of the technology in various ways (such as through engagement with feedback devices and sensory forms of feedback) (see Section 3.6.2). The range of ways in which different technologies are incorporated into household routines will be assessed in this research:

Research question: To what degree does LZC technology exhibit agency in everyday temporal affairs? (→ Section 7.4)

Research question: To what extent does feedback from LZC technology engage householders and shape actions? (→ Sections 7.4)

Conversion of LZC technology: At the conversion stage, the personal meanings assigned to LZC technology and information relating to how it works and performs is communicated by householders to others. As noted previously, the circulation of personal meanings contributes to the on-going development of the meanings attached to these technologies by associated others (Hynes & Rommes, 2006). This may then influence the course of domestication processes followed by these others if they are or become users of the technology, as discussed in Section 3.6.1. Future new users encompass those that actively purchase and retrofit LZC technology and those that actively or passively acquire such technology when purchasing or renting homes fitted with them. For existing users, these conversion stages within others' domestication processes have the potential to lead to changes in the way that they domesticate their own technology. In this research, I assess the extent to which householders engage with the conversion stage of domestication:

Research question: To what extent do households in a given development provide LZC technology-related support to each other? (→ Section 9.3)

Research question: To what extent do new home occupants recommend their LZC technology to others and have these others proceeded to install technology? (→ Section 9.3)

This research reflects on the nature of domestication processes observed in multiple households. According to Bakardjieva (2006, p. 71):

> ‘Not enough reflection has been done on what the results of domestication processes are and what they add up to when similarities and differences in patterns of use across households are examined.’

She goes on to enquire whether domestication theory can:

> ‘furnish a *critique,* an examination of domestic practices and their larger social consequences from a normative perspective oriented toward change?’ (Bakardjieva, 2006, p. 71)

With the desired outcome from the policy-makers’ perspective taken to be the optimisation of installed LZC technology, I evaluate the research findings in Chapter 10 to identify what changes (such as to structures, routines and communications) might help deliver improvements to the current situation.

Sørensen (1997, p.5) comments that:

> ‘The outcome of a collective process of domestication of a technology may be that it becomes *entrenched.* This means that the technology is made part of a stable sociotechnical arrangement in a way that makes it increasingly difficult to do away with.’

Where entrenched technologies (such as conventional heating systems) are substituted or supplemented with new technologies, the domestication of these ‘may be a source of destabilisation in the sense that new meanings or new practices may be constructed’ (Sørensen, 1997, p. 5). Where new technologies require a change in current routines in order to optimise their functionality (as with certain LZC technologies), a process of destabilisation and restabilisation is an important component of a successful domestication process[70]. However, Sørensen et al. (2000, p. 253) highlight that ‘knowledge cannot be assumed to piggyback upon technology’, and the extent and manner in which knowledge relevant to optimising LZC technologies has been successfully transferred to users is considered in this research (see Section 3.7):

Research question: What are householders’ perceptions of the written instructions provided for LZC technology? (→ Section 6.3)

Research question: What verbal instruction on LZC technology is provided on moving in? (→ Section 6.4)

[70] According to Berker (2011, p.261): ‘Successful domestication is defined as mutual adaptation including practical, symbolic and cognitive activities. If one of these dimensions is absent, then domestication is not complete.’

As highlighted previously, once domesticated new technologies may later become de-domesticated or re-domesticated (Hynes & Rommes, 2006). This notion of re-domestication is particularly apt for LZC technology. When current occupants move elsewhere and those from elsewhere move in, the process of domestication re-commences, though from a different starting point or set of socio-technical relations. The identity of the user(s) will have changed (along with their knowledge, abilities, values and wider network of human and non-human entities) and the technology's performance may have deteriorated due to a lack of maintenance. Relevant guidance documentation on the technology may have been mislaid but, on the other hand, the former occupants may impart valuable advice to the new householders at the handover stage. This aspect of re-domestication is assessed:

Research question: What knowledge do departing residents impart to new users of LZC technology? (→ Section 6.5)

As discussed in Section 3.4.4, Lehtonen (2003, p.364) interprets domestication as a series of 'trials' which concern the user, the technology and other pertinent entities (Lehtonen, 2003). The nature of such trials, which contribute to the development of LZC technology-user associations, is questioned in this research:

Research question: What trials (experiences, interactions or receipt of new knowledge) trigger householders to shift and re-stabilise their socio-technical relations as part of the on-going domestication process? (→Sections 7.5 & 10.6)

In this section, I have demonstrated how the technology studies version of domestication theory provides a useful framework for studying the socio-technical associations between householders, LZC technology and other pertinent entities, and I have demonstrated how the theory has influenced the derivation of certain research questions. The aim of the research was to use the technology studies version of domestication theory in an interventionist way (Vikkelsø, 2007). The approach was employed to generate a description (and explanation) of the state of LZC technology-user associations within the selected population. The aim of the research was then to use these findings to guide the formulation of interventionist strategies aimed at improving the CO_2 reduction potential of LZC technology-householder associations within the selected population; specifically, the last research phase was to constitute a form of action research, as now discussed.

4.3 Action research & participatory action research

In this section, I briefly consider the action research mode of inquiry, which was to underpin the final research phase (see Section 5.3). This phase did not proceed as envisaged as the research participants did not sufficiently engage with it (see Section 5.4.3). However, the underlying intentions of the action research approach contributed to the formulation of the research design and it is therefore drawn attention to in this section (and further discussed in Appendix 2).

The purpose of action research is to, firstly, gain an improved understanding of a particular situation (via the generation of relevant knowledge) and to, secondly, facilitate a desired change to that situation (Helmfrid, Haden, & Ljung, 2008; Barton, Stephens, & Haslett, 2009). This second stage differentiates action research from traditional scientific research, where the prime motivation is to understand a situation but not to directly strive to change it (as elaborated on in Appendix 2).

Within human geography, Pain (2003) identifies three forms of action research: activist, participatory and policy-related, acknowledging that these research modes 'are not discrete but often overlap in practice' (Pain, 2003, p. 651). It was intended that this research would employ elements of each of these modes. Firstly, the research incorporated an activist element as it was my normative goals relating to climate change that set the overall direction for the research. Secondly, participatory action research (PAR) (as discussed in Appendix 2) refers to the end of the action research spectrum of approaches where the focus is on fuller active participation by those involved in the research, which was sought in the final research phase. Thirdly, the subject matter underpinning the research was policy-relevant, pertaining to both local and central government policy (see Sections 2.4 and 2.3 respectively).

The first two research phases (a survey and interviews, as detailed in Section 5.3) were conducted on householders. The third research phase was intended to be more participatory, as subsequent stages of research planning and action were envisaged as being jointly developed with participating householders, to meet their own needs. A more in depth evaluation of this element of the intended research approach (that did not transpire) is provided in Appendix 2. In Sections 5.3 and 5.4, I discuss the endeavours made to promote the research's PAR component and consider why this was unsuccessful. In Section 10.7.1, I explain the change in research trajectory that ensued.

4.4 Research questions

Within the literature review, encompassing Chapters 3 and 4, I have highlighted various research questions which will aid further understandings of how new home occupants come to use, regard, interact with and be influenced by pre-installed LZC technology. Addressing these research questions has (1) helped focus and guide the research design, data analysis and discussion generated, (2) helped ensure the research contributes to the extant academic literature and (3) contributed to creating knowledge of relevance to attempts to reduce CO_2 emissions from new builds[71]. Overall, addressing the research questions will contribute to a better understanding of the extent and manner in which LZC technologies are domesticated within new homes.

The various research questions are addressed in Chapters 6 to 10, as outlined in the following summary of research questions:

Chapter 6. Moving in with LZC technology

To what degree are LZC technologies actively appropriated in new dwellings?

What are householders' perceptions of the written instructions provided for LZC technology?

What verbal instruction on LZC technology is provided on moving in?

What knowledge do departing residents impart to new users of LZC technology?

Chapter 7. Getting on with LZC technology

Which sources of information do householders refer to in order to improve their understanding of LZC technology?

How are users configured by the design, placement and settings of LZC technology?

To what extent does feedback from LZC technology engage householders and shape actions?

To what degree does LZC technology exhibit agency in everyday temporal affairs?

[71] These dual outcomes satisfy King et al.'s (1994, p.15) two criteria for social science research: firstly to '*pose a question that is "important" in the real world*' and secondly, to '*make a specific contribution to an identifiable scholarly literature*'.

What trials (experiences, interactions or receipt of new knowledge) trigger householders to shift and re-stabilise their socio-technical relations as part of the on-going domestication process?

Chapter 8. Processes of maintenance and repair

What is the prevalence and cause of faulty LZC technology and how do these faulty installations come to light?

To what extent are LZC technologies maintained and what are the underlying reasons for this?

What are the wider benefits of maintenance processes?

Has any on-going communication been received or feedback sought in relation to the LZC technology?

Chapter 9. Intra-household and inter-household dynamics

Intra-household dynamics

Do LZC technologies slot into existing gendered patterns of everyday life?

What symbolic meanings do new home occupants attach to LZC technology and do these ascribed meanings effect how the technology is used?

Inter-household dynamics

To what extent do households in a given development provide LZC technology-related support to each other?

What role do Residents' Associations play in facilitating information exchange and assisting with formulating neighbourhood norms?

To what extent do new home occupants recommend their LZC technology to others and have these others proceeded to install LZC technology?

Chapter 10. Domestication processes

What trials (experiences, interactions or receipt of new knowledge) trigger householders to shift and re-stabilise their socio-technical relations as part of the on-going domestication process?

Chapter 5: Charting the research process

5.1 Introduction

In the last two chapters, I have identified the knowledge-gaps that the research addresses and the theoretical and methodological approaches that have underpinned the research. In this chapter, I go on to discuss how the research was executed in practical terms, and to highlight the ways in which the research questions and the theoretical and methodological approaches guided the design of the research process.

I commence by describing and justifying the adopted research strategy, the three constituent phases of fieldwork, and the research methods utilised (Section 5.2). The *planned* research phases comprised, sequentially, a borough-wide survey for new home occupants, semi-structured householder interviews and the creation of a householder support network (which represented the intended PAR component of the study). I proceed in Section 5.3 to cover matters relating to research preparation, including study area selection, questionnaire design, the interview strategy and ethical considerations. Section 5.4 then describes the three phases of fieldwork. The reliability of the fieldwork data and its analysis are discussed in Section 5.5, and Section 5.6 concludes the chapter with a description of the research participants and their LZC technologies.

5.2 Research methodology & methods of data collection

5.2.1 Research strategy

From the literature review, various research questions emerged as reflecting worthwhile areas of investigation that could contribute to current knowledge. Although presented in one account, the review was conducted in two phases. The first review generated three preliminary research objectives that determined the initial research design (Section 5.3). The second review continued throughout the fieldwork, data analysis and writing-up stages, as partly driven by emergent findings. Subsequently, the research objectives were refined to yield the research questions ultimately addressed (Section 4.4).

The perspectives that informed this thesis (Chapter 4) influenced the ways in which research questions were formulated, the research conducted, data evaluated, findings derived and interventions initiated. The technology studies version of domestication theory, for example, contributed to the framing of research questions and to the way data was collated as part of the derivation of research findings. Additionally, the intention to ultimately follow a PAR mode of inquiry was built into the design of earlier research material in order to illicit interest in this from potential participants.

Broadly, this thesis aims to provide insights into how LZC technology-user associations develop in new homes and what factors influence this. Based on these insights, the research aimed to initiate a process of intervention to promote informed changes. In essence, then, the research aimed to be exploratory and descriptive (*how* are things at present?), explanatory (*what* has influenced this state of affairs and *why* has this happened?) and interventionist (*what* now?) (Robson, 1993).

A research study's overall approach is referred to as its research strategy; the three main types being experiments, surveys and case studies (Robson, 1993). Any given study may employ a single, multiple or hybrid strategies – the main determining factor is that the selected approach is appropriate for the question type posed (that is, how, why, what…) (Robson, 1993). In this study, multiple question types are posed and the research strategy reflects this through combining elements of a survey and case study. With regards to the case study element, the context of the study is the implementation of a local LZC energy policy but the targets of the study, and the units of enquiry, are the representatives of the interviewed households.

5.2.2 Research phases, sampling techniques & mixed methods

The methodology underlying the planned research phases progressed from one where information was gathered *about* participants to one where information was to be generated *with* and acted on *by* participants. These phases provided different potentials for exploratory, explanatory and interventionist elements. To deliver against this changing methodological emphasis, a mixed methods approach was selected for data generation.

In the main exploratory phase (Phase 1), I sought to capture the views of as wide a population as feasible, targeting all applicable households within a borough. To deliver this breadth of reach, a questionnaire survey was selected as the optimum research method[72,73]:

[72] Surveys can be used to describe, analyse or explore situations (Robson, 1993).
[73] Surveys have been used elsewhere in domestication studies (Haddon, 2006).

Phase 1: A cross-sectional questionnaire survey[74] encompassing new home occupants (October 2011 - January 2012).

In the main explanatory phase (Phase 2), I aimed to discuss aspects of the LZC technology-user association with householders in order to identify and understand the main influential issues. To enable this depth of inquiry, interviews were selected as the most appropriate research method[75]:

Phase 2: Semi-structured, qualitative interviews with new home occupants (February - June 2012).

In the interventionist phase (Phase 3), I intended to help enable householders to start to address issues of concern. To facilitate the formulation and delivery of interventions, a PAR project (Section 4.4) was planned in the form of a householder support network:

Phase 3: Attempts to set up a householder support network (April - June 2012). An alternative form of intervention was ultimately pursued.

The Phase 1 survey encompassed any LZC technology, dwelling and housing tenure type. It was designed for maximum inclusivity within a defined geographical area (the jurisdiction of a local planning authority) and time frame (all homes built since the LZC energy policy adoption). This inclusivity, whereby the complete target population[76] affected by the policy was invited to participate, was intended to support the basis for any generalisations derived. This mode of purposive sampling (as opposed to probability sampling) is termed complete collection or criterion sampling (Teddlie & Yu, 2007).

Within the questionnaire, householders were asked whether they were willing to be interviewed. The interviewee sample was generated, therefore, by the first research phase, a mode of purposive sampling termed emergent sampling (Patton, 2002; Teddlie & Yu, 2007). This technique was also used to generate a group interested in the householder support network.

The use of different research methods (mixed-methods) is a common approach (Patton, 2002) advocated by a number of researchers (Beazley & Ennew, 2006), including human geographers (such as Hemming, 2007; Yeager & Steiger, 2013; Lombard, 2013 and Lobley, et al., 2013), partly because it enables the robustness of results generated by different methods to be

[74] One used to provide ‘a description or portrait of one group’s opinions at a particular time’ (Fink, 1995, p. 23).
[75] Common to domestication (Haddon, 2006) and ANT studies.
[76] Based on evidence collated.

partially evaluated through a process of cross-checking (Winchester & Rofe, 2010). In this research, survey and interview data were analysed separately but then merged appropriately when addressing research questions.

Creswell (2009) outlines six forms of the mixed-methods approach, which differ in terms of the timing of method application, the weighting given to the data generated by each method, the ways and stages at which data is mixed, and the extent to which a theoretical framework guides the research. The form most closely aligned with this research is what he terms a 'sequential transformative strategy' (Creswell, 2009, p. 212), characterised by two data collection phases[77], a theoretical perspective that shapes the research questions as applied to an issue of concern, and recommendations for addressing aspects of this issue. In this research, there were three planned, but two eventual, data generation phases; theoretical perspectives shaped the research questions; and the research was intended to be action-oriented in its last stage.

The research's notional unit of enquiry was the household, where all members could potentially be considered as LZC technology users. In practice, an adult representative completed each questionnaire and became the contact point. The degree to which the viewpoints expressed in the questionnaires represented collective household responses or the respondents' individual views could not be ascertained. Viewpoints expressed by interviewees, however, could be probed to ascertain differences between household members, highlighting any gender differences, for example.

5.3 Research preparation

5.3.1 Study area & sampling strategy

Prior to selecting the study area, the LZC energy policies adopted by authorities in Berkshire and Surrey were reviewed to identify that likely to yield the most new homes with pre-installed LZC technology. During the process of translation (Cochrane & Ward, 2012) into borough-specific policies, the Merton Rule (Section 2.4) has mutated into divergent forms differing, for example, in terms of the target's magnitude and the development size above which it applies (Appendix 3). Additionally, the longer these policies have been implemented, the more homes ostensibly built to its requirements there will be. The optimum borough in

[77] Though mixed-methods research can entail more data collection phases (Teddlie & Yu, 2007).

which to conduct the research was deemed to be Woking, as Woking Borough Council (WBC) has required all new residential developments applying for planning permission between 2005 and 2012[78] to meet 10% of predicted energy demand via LZC technology.

Once selected as the study area in April 2011, I telephoned WBC's Planning Policy Officer responsible for climate change-related policies. The research's purpose and its potential benefits to WBC as a form of policy evaluation were discussed[79]. I established that WBC were able to provide a list of completed developments granted planning permission since 2005, though this data lacked accurate details on which LZC technologies were installed. This list, comprised of 812 dwellings, formed the initial focus for the survey (Phase 1a). Whilst distributing the questionnaire to these addresses (Section 5.4), I observed that WBC's list omitted certain new developments. To incorporate these, I searched WBC's planning database and identified 135 further dwellings, which then comprised Phase 1b of the survey.

5.3.2 Questionnaire design

The questionnaire (Appendix 4) was designed to ensure:

- the research intent was clear;
- the value of householders' contribution was emphasised;
- there were enough questions to yield sufficient data for subsequent analysis;
- its length would not deter householders;
- the wording and layout were clear;
- the confidentiality of returned information was assured; and
- participation in the follow-on research phases was encouraged.

The *initial* research objectives (subsequently replaced by the research questions (Section 4.4)), which shaped the design of the questionnaire were:

[78] This policy changed in October 2012. Now, developments need instead to attain a specified CSH level in relation to the energy component (WBC, 2013a).
[79] Engaging early on with WBC is aligned with an engagement approach termed 'translation research' (Summerfield & Lowe, 2012, p. 395). Here, enrolling policy-makers (or other stakeholders) into the research programme is part of the process followed to facilitate the translation of findings from 'fieldwork into practice' (Summerfield & Lowe, 2012, p. 395).

Objective 1: To conduct a post-occupancy evaluation of the incentives and obstacles that affect householder behaviour in relation to optimising installed LZC technology

- Output A: The characterisation of the socio-technical networks pertaining to householders and installed LZC technology, utilising concepts from ANT.
    - Addressed through Sections B and C of the questionnaire
- Output B: The identification of the main factors (incentives and obstacles) that affect householder behaviour in relation to the optimisation of installed LZC technology.
    - Addressed through Sections D and E

Objective 2: To assess the agentive power of LZC technology on users and others

- Output C: An assessment of whether the presence of LZC technology causes householders to behave or think differently to before, beyond the direct use of the technologies themselves, and whether there have been impacts beyond the household.
    - Addressed through Section C

Objective 3: To initiate the participatory creation of a householder support network to promote optimisation of installed technology

- Addressed through the 'Further research' section of the questionnaire

The questionnaire consisted mainly of closed questions, as recommended for self-administered questionnaires (Bourque & Fielder, 1995). Certain categorical questions sought contextual information relating to the respondent, their household and their technology. Section B of the questionnaire contained a list of statements and participants were asked whether, and to what degree, they agreed or disagreed with each. To facilitate the collation and comparison of responses, a five-point Likert scale was employed which presented a symmetric scale ranging from 'strongly agree' to 'strongly disagree'; this scale is well-established within social research (Litwin, 1995). To avoid confusion arising from the use of double negatives, only positive statements were presented against the agree/disagree scale, as advocated by Converse & Presser (1986) and Fink (1995). The disadvantage of this approach is that it can engender what is known as the 'acquiescence response set' (Converse & Presser, 1986, p. 38), whereby participants demonstrate a propensity to agree with statements regardless of their content. An evaluation of whether this occurred appears in Appendix 5.

Sections B and C presented various incentives and obstacles to improving the performance of the technology, and participants were asked to rate the significance of each factor from a five-point scale ranging from 'extremely significant' to 'not at all significant'. Factor selection had been informed by the literature review (Chapter 3), as advocated by Bourque & Fielder (1995). Blank spaces were provided at relevant points to enable participants to exemplify their responses or to identify additional factors of significance. The format of the different sections was varied to assist with retaining the participants' interest throughout, as advocated by Converse & Presser, 1986.

I discussed the draft questionnaire with WBC's Planning Policy Officer to gain a practitioner's perspective on how it could be improved upon, both in terms of clarity and in its potential to generate policy-relevant and usable knowledge. The Officer recommended the following changes:

1. Under the question 'What type of LZC technology is installed in your home?', increase the clarity of two selection options:
    - change 'solar thermal panels' to 'solar thermal panels (→ hot water)'
    - change 'photovoltaic (PV) panels' to 'solar PV panels (→ electricity)'
2. Under the question relating to housing type, change the wording of one selection option to a more sensitive term:
    - change 'a council house/flat' to 'a house or flat rented from the Council'
3. Consider asking whether residents are members of residents' associations, as these may prove useful contacts:
    - Insert 'If you are a member of a residents' association, please give its name'

These suggested amendments were adopted; given their minor nature, the prospect of my research being co-opted by the local authority was not an issue of concern.

I also e-mailed the draft to Professor Tim Unwin at Royal Holloway who, within the Department of Geography, is recognised as being experienced in questionnaire designs. Feedback was obtained on its length, clarity and layout, and some amendments were made accordingly to the sequencing and wording of questions. For example, questions relating to personal information, such as household income, were moved from the start to the end, a placing also advocated by others (Converse & Presser, 1986). The rationale for this is that placing what might be viewed as sensitive or uninteresting questions at the beginning may increase the probability of householders disregarding the questionnaire (Bourque & Fielder, 1995).

To encourage questionnaire completion, I considered it advantageous to state that WBC endorsed the research, as it might have bolstered people's perception of the research's legitimacy. Associating the research with WBC may, however, also have potentially alienated any residents dissatisfied with the Council. I asked the Planning Policy Officer if I could state that: *'This research project is endorsed by WBC'*. I was informed, instead, that I could use the following wording, which was adopted: *'This survey has been undertaken using information supplied by WBC'*.

In order to test the questionnaire's readability, a new housing development outside the borough of Woking (in Bagshot, Surrey) was selected for a usability trial. In September 2011, I discussed the questionnaire with four householders (male and female), whose homes were of various tenure types (Council-owned, shared-ownership and private housing) and built forms (terraced and semi-detached). All had either a STHW or PV system. The conversations were not prearranged but were determined by those that were in at the time and willing to participate. The householders were asked to read selected questions to establish whether they comprehended correctly their intended meaning. This form of focused testing is termed a 'participating pre-test' (Converse & Presser, 1986, p. 52), whereby the householders participated in the direct assessment of, and improvement in, the questionnaire's usability. Useful feedback was obtained leading to the rewording of certain questions. Two householders agreed to complete and return the full questionnaire. One of these questionnaires was received and had been completed as envisaged.

Keeping the questionnaire to a manageable five-page document restricted the space available to expand on the research's purpose; to cover this, a letter accompanied the questionnaire (Appendix 6). This letter went through various revisions during the course of the survey with the aim of improving householder engagement. For example, one change involved the switch from plain to University letter-headed paper, to emphasise the research's academic focus and legitimacy (Bourque & Fielder, 1995).

As a self-funded student at this stage[80], I was keen to avoid unnecessary costs. I initially planned to post the questionnaire twice to each household with a stamped-addressed envelope (SAE) included for the questionnaire's return. Due to the large number of developments, however, the estimated cost of this was £2350. The literature on postal surveys suggests that a response rate of no more than 20%[81] should be expected, which meant SAEs were a financially wasteful option. Instead, a Response Service was set up through the Post

[80] I later received a Postgraduate Research Award from the RGS-IBG.
[81] For unsolicited mail-based surveys, where no incentives for completion are given and one mailing is sent, a response rate no greater than 20% is expected (Bourque & Fielder, 1995).

Office, whereby postage costs were only incurred for those questionnaires returned in the Freepost™ addressed envelopes provided.

5.3.3 Interview strategy

The interview questions addressed the same overall research objectives as the questionnaire but were designed to enable a broader and deeper inquiry into the development and nature of LZC technology-householder associations. Interviewees had, in all but one case, previously completed the questionnaire, enabling interview questions to be tailored. Additionally, early analysis of the survey data enabled emergent ideas and findings to be probed further during the interviews, an approach employed by Osmani & O'Reilly (2009b). An early review of the survey data with the Planning Policy Officer also assisted in ensuring that particular points of interest for WBC were encompassed within the interview questions.

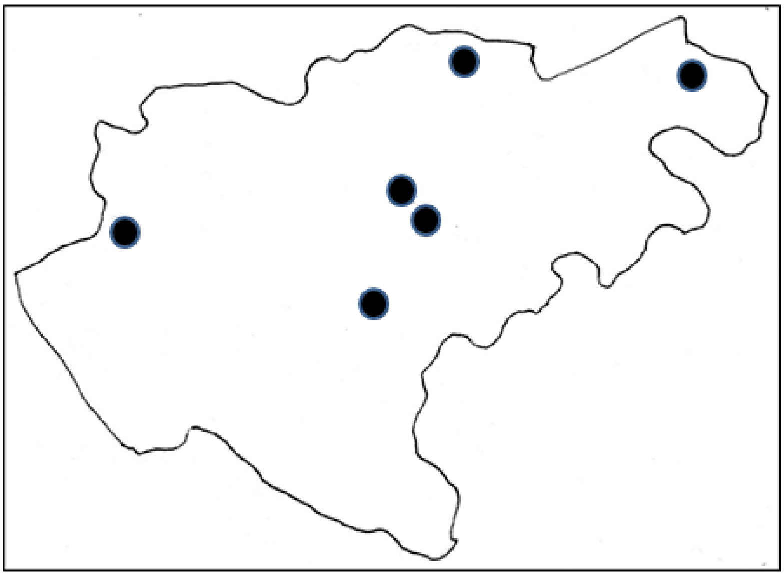

Figure 5.1. An outline map of the borough of Woking illustrating interview locations

Early discussions with the Planning Policy Officer indicated that WBC could make interview venues available, both within Woking centre and around the borough. A schedule of available interview times and locations was then compiled. This offered a geographical spread of six venues (Figure 5.1) (to minimise interviewees' travel distance) and morning, afternoon and evening sessions distributed across weekdays and weekends (Appendix 11). It was appreciated that using venues associated with WBC might potentially alienate any residents dissatisfied with the Council. On balance, however, it was deemed an advantage due to its potential to bolster residents' perception of the legitimacy of the research. The venues were also free to use and offered a secure environment for both the interviewees and myself.

An overarching list of questions (Appendices 7 and 8) was posed to each householder and, dependent on the responses, these lines of inquiry were further explored to varying degrees. This semi-structured format, consisting of mainly open questions, enabled interviewees to talk in greater depth about issues of particular relevance to them. Through facilitating such fuller discussions, significant but unsuspected issues of relevance can emerge. At the same time, a semi-structured format affords a degree of consistency across interviews (Gill, et al., 2010), which enables trends and variances to be discerned during the comparative analysis (Baxter & Eyles, 1997).

A Participant Consent Form was presented to interviewees to sign (Appendix 9); this gave permission for the interview to be recorded, which yielded two benefits. Firstly, it enabled the accurate recall of what transpired and, secondly, it freed me up to listen attentively to what householders were saying and to steer the interview to address emerging issues. The Participant Consent Form made it clear that the interviewee could stop the interview at any time and that the recording would only be used for my research purposes.

I envisaged that up to 30 interviews would be held. If more than 30 willing participants had emerged, than purposeful sampling of these would have yielded interviewees whose circumstances reflected the widest possible variation against the following criteria: LZC technology type, housing type, tenure, household composition and age. Patton (2002, p.234) identifies this mode of purposeful sampling as 'maximum variation sampling' and attributes the following strength to it:

> 'Any common patterns that emerge from great variation are of particular interest and value in capturing the core experiences and central, shared dimensions of a setting or phenomenon.'

As it transpired, all those willing to be interviewed were interviewed as this numbered 27. These interviewees exhibited considerable variation against the relevant criteria; their households contained the six most prevalent types of LZC technology, dwellings contained one to six bedrooms, all six age bands were represented, as were three of the four tenancy types identified by the questionnaire respondents (Section 5.6).

5.3.4 Promoting the PAR component

Phase 3 of the research was to involve the setting up and facilitation of a householder support network. It was appreciated that this venture might not succeed as it depended on the willingness and ability of participants to fully engage with the research. Therefore, in designing the research process, the enrolment of potential participants into this network was a guiding factor. Firstly, within the questionnaire, the concept of the network was introduced and interest in it elicited (refer to the 'Further research' section of the questionnaire). Encouragingly, 34 of the 122 survey respondents wanted to be kept informed of this network's development. Secondly, during the interviews I discussed the network and obtained ideas on what interviewees would like to get out of it.

5.3.5 Ethical considerations

I gave attention to ethical considerations throughout this research, as advocated by Dowling (2010). From the outset, the overriding aim of the research was to contribute to, and act upon, knowledge that would be of environmental significance; the research objectives and then research questions were framed with this in mind. Attempts were made to make the research as inclusive as possible within the target population, ensuring all householders had an opportunity to express their views and contribute to the research.

Householders were not coerced into answering questions; for both the survey and interviews, participants were informed that they could leave out questions they did not wish to answer. A Participant Consent Form was signed by those interviewed face-to-face giving permission for proceedings to be recorded (Appendix 9). For those interviewed over the telephone, the content of this Form was verbally relayed and verbal consent to the interview was given. The content of this Form complied with Royal Holloway's guidance on how to conduct research in an ethical manner. Additionally, interview and exhibition locations were selected to ensure the safety of participants and myself.

It was considered ethical to share findings with those that had contributed to the research or who might find it of interest, a stance supported by Baxter & Eyles (1997). Hence, the initial findings were fed back to the target population via a posted summary and via a householder exhibition (Section 5.4). Within these and other research outputs, the anonymity of research participants' contribution and the confidentiality of their personal details were ensured.

5.4 Conducting the research

5.4.1 Questionnaire survey

The initial plan was to post the questionnaires. However, the size of the target population prompted a reconsideration of this due to the associated costs. Instead, the questionnaires were personally distributed, which had its advantages; it enabled me to identify the housing type at each address and also to pinpoint developments that had been omitted from Phase 1a of the survey. The envelopes were addressed to 'The householder' (in order to encompass home owners, renting tenants and female and male residents), followed by the address.

Each questionnaire had a unique numeric identifier associated with the delivery address, as advocated by Dillman et al. (2009). Using this tracking method, it was clear who had responded. Two to three weeks after the first distribution, a second copy was delivered to non-respondents. This tracking method saved on material resources and time. The unique identifier also revealed whether those that participated completed the first or second questionnaire; 70% of respondents completed the first copy whilst 30% completed the second.

When delivering the second copy, I knocked on doors; those householders I spoke with were encouraged to complete the questionnaire and some gave useful feedback. This occurred at different times of the day, and during both weekdays and weekends, to try and avoid biasing unduly the make-up of those that returned the questionnaire. For blocks of flats, internal doors were not knocked on due to restricted access to internal corridors and personal safety concerns.

Door-step conversations were held with 44 householders believed to have LZC technology. The male: female ratio of those spoken to was 1:1.3. In total, 30% of these householders went on to return a completed questionnaire. By gender, 24% of households where the female was spoken to went on to return the questionnaire compared to 37% of households where the male was spoken to. Those that returned completed questionnaires were e-mailed or posted a thank you letter.

5.4.2 Conducting interviews

37 householders indicated on their questionnaire that they would, or might, be willing to be interviewed. I promptly e-mailed them back, where possible, stating I would re-contact them

with a selection of interview venues and times. There was a maximum interval of three months between the earliest returned questionnaire and the dispatch of the suggested interview schedule (Appendix 11). This gap resulted from the unexpected need to extend the survey into a second phase (Phase 1b). During this interval, some would-be participants moved away from the area, changed their minds about participating or did not respond to attempts to re-contact them. In the event, 26 full householder interviews were held and these ranged in length from 50 to 90 minutes, but most were approximately 60 minutes long as intended. In addition, a partial interview was held where the interviewee had to leave after 15 minutes. 25 interviews were held face-to-face and a further two were conducted by telephone. The 27 interviewees were comprised of thirteen men, eleven women and three mixed couples.

Interviews were held between February and June 2012. Certain householders were away for prolonged periods of time, on work or on holiday, which necessitated a degree of flexibility in the scheduling. Most interviews took place in one of the suggested venues but, departing from the initial plan, six interviews were held in participants' homes. This arrangement was made with women or couples after this was established as their preferred option (as they had young children to attend to or they wanted to show me aspects of the LZC technology). In each of these instances, as a precaution, I left information with someone on where I was going, who I was meeting and when I should be back.

Due to errors in using the recording equipment, two interviews were not recorded. In one instance, the error was immediately realised and relatively reliable notes were made. In the other, the error was realised some time afterwards and it was then unfeasible to generate reliable notes. To summarise, the following outputs were obtained from the householder interviews: 24 complete transcripts of full length interviews, one transcript of a partial interview and one set of interview notes from a full length interview.

5.4.3 Endeavouring to follow the PAR approach

Throughout the research, sustained efforts were made to develop a relationship with the research participants. For example, subsequent to the interviews, there was frequently e-mails exchanged following-up on matters discussed. If people had expressed an interest in participating in the householder support network, they were kept updated on this.

Before actively commencing on the PAR phase, I posted a six-page summary of selected initial results (Appendix 12) to those deemed to have LZC technology, regardless of whether they had participated in the survey[82]. Included within this mailing were two invitations; one to an exhibition of the full set of initial research results, and the other to the launch of the householder support network (Appendix 13). The exhibition was held between 1pm and 3pm on a Sunday in April 2012 and the network launch was scheduled to start at 3.15pm the same day. The two events were arranged to run consecutively for three reasons. Firstly, for those interested in both events, they would only have the inconvenience of one trip out. Secondly, it was considered that the exhibition could act as a draw for people, who might then be encouraged to stay and participate in the network launch. Thirdly, the detailed presentation of the existing situation as contained within the exhibition posters, as well as the posted summary, was to help form the basis for an initial joint reflection of the preliminary research findings (an integral part of PAR (Appendix 2)).

In selecting a venue for the householder exhibition, care was taken to find a central, well-known and appealing venue; that chosen was the Lightbox[83], a modern exhibition space and art gallery (with free entry), built to high environmental credentials and located in Woking centre. This venue was suggested by an interviewee, and it transpired that most of those interviewed knew of it. I hired a spacious room and bedecked it with 10 A1 posters containing the detailed initial results (Appendix 14). There was also a map of the borough upon which participants could mark, using coded stickers, the technology type installed and their home's location. To capture information on the attendees' view of the research, I provided a feedback sheet (Appendix 15). In addition, material for the launch of the network was positioned around the room. This consisted of two flipcharts with pre-prepared notes on possible questions to address and topics to debate.

Those who had expressed interest in the network were encouraged to attend the network launch. Despite a reasonable level of initial interest, as the day approached I received a number of e-mails from householders explaining why they would not be attending (due to family commitments and holidays, for example). These constituted 12 out of the 34 who had expressed an interest in participating. This did not bode well, but I was hopeful that a reasonable number might yet attend the exhibition. A total of 64 surveyed householders had ticked the box asking to be kept informed of the research results, and it was hoped that this

[82] By this stage, I had been awarded a Postgraduate Research Award from the Royal Geographical Society which covered the costs for this mailing.
[83] (http://www.thelightbox.org.uk/)

declared level of interest would translate into a reasonable footfall at the exhibition. In the event, only three householders from the target population attended the exhibition (two of which had been interviewed), plus some general members of the public. Only one person attended the network's launch, which was therefore unsuccessful and could not proceed as envisaged, as this involved promoting a discussion between householders on various aspects of their installed technology (see Appendix 16 for a detailed planned agenda for the launch, informed by sources such as Chambers (2002) and Seeds for Change (2009)).

In reflecting upon why the planned network did not materialise, the nature of the researcher-participant relationship was considered. The importance of relationships to PAR is noted by Pain et al. (2007b, p.227), who consider that the quality of the relationships generated, including 'the trust that is established', will determine whether any attempt at PAR is successful. In this research, however, it is not considered that the PAR stage came aground due to a lack of trust between the potential participants and myself. For example, all householders interviewed readily agreed to being recorded, which suggested adequate trust had developed. It may, alternatively, have been that experiences with installed LZC technology had not led householders to be sufficiently driven to participate in the way envisaged, unlike communities that might be driven, for example, by thoughts of social or environmental injustices (Chalmers & Colvin, 2005). Participation in the envisaged network would have necessitated householders disrupting their existing routines, to a certain degree; thus, the drive to participate and/or the perceived benefits of enrolling in this network failed to outweigh the willingness or ability of householders to easily depart from existing routines. This idea parallels Marres' (2010, p.193) discussion on John Dewey's notion of publics, which contends that it is 'the rupture of habitual ways of doing, which results in the formation of a public.'[84]

Given the disappointing network launch, it was evident that regular physical gatherings, of a relatively consistent group of householders, were not going to materialise. Instead, more virtual and/or informal manifestations of the network were contemplated, although such alternative formats were considered unlikely to constitute suitable vehicles for the delivery of the PAR project. However, I felt that another attempt at creating some form of network was justified given the number initially interested. Two informal modes of promoting a network were therefore trialled. The first was envisaged as an informal, monthly evening get-together at a local café. The second was the creation of an on-line forum where local residents could

[84] Publics, in Marres' (2010, p. 192) reading of Dewey's writings, arise when people are affected by 'harmful' and 'extensive and enduring' consequences, for example.

discuss their technology. These two trials were viewed as forms of intervention that could promote the optimisation of installed technology, as opposed to any form of action research.

These two further attempts to establish a network also foundered. Two evening get-togethers were held at a café in June 2012. An on-line poll established the most convenient dates to meet but only one person attended on each occasion, which was insufficient to support any viable network. With respect to the on-line forum, this was trialled via Google Groups in June 2012. One householder in particular tried to stimulate some debate, but this proved unsuccessful and only a few postings appeared. It seemed that there were too few people (five) signed up to the forum to sustain any initiated debate.

I originally planned that the experiential knowledge harnessed from the PAR project and from the first two research phases, would be fed back to third parties (such as WBC and locally-active developers) near the end of the research. As the PAR project foundered, an alternative option was considered which involved engaging, more actively, with one or more of these groups to begin to address some of the issues highlighted. The need to diverge from the envisaged research trajectory highlights the need for researchers to respond in a considered way to changing circumstances, which in this case involved acting upon the research findings with an alternative group; namely, the local authority. This involvement with the local authority and the resultant policy impact of the research are discussed in Section 10.7.1.

In the next section, I return to Phases 1 and 2 of the research and discuss the ways in which the research data was collated and analysed to address the research questions.

5.5 Analysis of research data

5.5.1 Survey reliability & collation of survey data

In evaluating a survey's reliability, four error types are relevant: 'coverage, sampling, non-response and measurement' (Dillman, Smyth, & Christian, 2009, p. 16). *Coverage errors* occur when, firstly, not everyone within the target population has the potential to be included in the survey sample and, secondly, when there are pertinent differences between those that are excluded and included (Dillman, Smyth, & Christian, 2009). To minimise coverage error in this research, a three-pronged approach was followed to comprehensively identify the target population: the use of WBC's 'Completed permissions' database, an additional search of the planning applications database and field observations. If any pertinent developments were unknowingly excluded from the target population, there are no known reasons why they would differ in any significant regard from those included. Thus, it is considered that the coverage error has been minimised.

Sampling errors are a product of sampling techniques and can be minimised by improving the representativeness of the surveyed sample as compared to the target population. In this research, the sampling error was eliminated by encompassing the full target population in the survey; that is, the survey sample equated to the target population.

Non-response errors occur when those 'who do not respond are different from those who do respond in a way that is important to the study' (Dillman, Smyth, & Christian, 2009, p. 17). Given the 83% of non-responses to this survey, the significance of any non-response error warrants consideration due to the potential for differences in opinions, experiences and other factors between respondents and non-respondents (Fink, 1995). WBC possesses scant information on the characteristics of households and LZC technologies occupying new builds. Information on installed technology could be compiled from submitted SAP energy assessments (Sections 2.2 and 3.2) but this does not appear to take place. However, there is WBC data on the built form and the volume of social housing against which the representativeness of the respondents can be assessed. 11% of survey respondents resided in social housing (Section 5.6) compared to an estimated 14% in the target population. Additionally, within the surveyed respondents, occupants of flats and terraces are slightly under-represented compared to occupants in semi-detached and detached properties, which are over-represented (Section 5.6). It is difficult to assess whether and how the non-representativeness of the survey respondents in these regards may impact on the reliability of the research findings. However, if deemed relevant, the potential impact of these slightly non-representative characteristics of the respondents will be reflected upon in the ensuing discussion chapters.

Measurement errors reflect how accurately the respondents complete the survey (Litwin, 1995). Such errors are attributed by Dillman et al. (2009) to how the questionnaire is worded and designed. However, in this survey, the only evidence of measurement error arose from certain respondents' lack of knowledge regarding the type of LZC technology installed. As mentioned earlier, it was established that a few respondents had misidentified their technology, which introduced a measurement error not attributable to the questionnaire's design. The incidence of this misidentification error by respondents is unknown.

Although not a measurement error as such, the potential for gender to affect the ways in which one or more survey questions were answered was noted (Section 9.2.4). The survey design was gender-neutral; each questionnaire was addressed to 'The householder' and it requested that an adult complete it. As detailed in Section 5.6, 59% of those that completed the questionnaire were male. In joint households[85] it was, with one exception, stated that the responsibility for operating the LZC technology was either one that resided with the male adult or jointly amongst adults in the household. Thus, it may be that more males completed the questionnaire as they were more likely to regard themselves as responsible for operating the technology. The question to then address is whether the ways in which the questionnaire is completed is influenced by gender (a finding reported by Cloke (2001)). The potential impact of respondents' gender on the research findings is explored in Section 9.2.4.

The survey results were collated and graphically presented using Excel spreadsheets and PowerPoint (for the exhibition posters). The collated survey data was used to yield information relevant to the research questions. Although survey results are often interrogated using quantitative statistical techniques, I did not consider that this would have assisted in further addressing the research questions, which in general required a more qualitative and holistic treatment of the data.

5.5.2 Transcription of interviews

Each interview recording was transcribed into a Word document. The analysis and discussion of the interview material was then guided by coding and triangulation:

Coding - Three layers of coding were applied. The first layer of 'connective' coding linked each research topic[86] to relevant extracts within each transcript. A second layer of 'descriptive' coding was used to codify the content of these extracts; this coding used response codes that emerged from the responses (Castro, et al., 2010) and these codes assisted with data reduction and organisation. To assist with data interpretation (Cope, 2010), a third layer of 'thematic' (analytical) coding was used to group together response codes that had 'functionally equivalent meaning' (Castro, et al., 2010, p. 348; Abdel-Wahab, Moore, & MacDonald, 2011). The derivation of such thematic categories is driven by '*recurring regularities*' (Patton, 2002, p. 465) observed in the data and the aim is to represent all response codes. The weighting of

[85] Where there were at least two adults.
[86] Pertaining to one or more research questions

each thematic category, as determined by the number of affiliated response codes and the frequency of their occurrence, can then be used to assess the significance of each thematic category.

Triangulation - The verification of findings was supported by data triangulation (via multiple sources) and methodological triangulation[87] (via multiple methods) (Patton, 2002). As explained by Baxter & Eyles (1997, p.514), triangulation 'is based on convergence: when multiple sources provide similar findings their credibility is considerably strengthened.' The interview findings were triangulated with pertinent survey results (enabled by the overlap between questionnaire and interview questions), door-step conversations (from others in the same development) and via comparisons of interview extracts.

Verbatim quotations have been incorporated throughout Chapters 6 to 9 to support points made. As argued by Baxter & Eyles (1997, p. 508):

> 'Quotations are important for revealing how meanings are expressed in the respondent's own words rather than the words of the researcher.'

A pertinent range of quotations is provided where a single quotation would be unrepresentative of the wider findings.

5.5.3 Assessing the validity of inferences

Given the ratio of interviewees to the target population, how can the validity of inferences made from collated interview material be judged? The use of statistical methods for this sample size (n=26) would be inappropriate and Bailey et al. (1999, p.172) contend that 'the idea that one can only make data-construct links (from description to theory) when one is dealing with a large 'representative' dataset' is not applicable to qualitative research. Instead, it is the validity of the analysis that requires attention (Bailey, White, & Pain, 1999).

The thematically coded interview material was collated and analysed for trends and disparities in preparing the discussion on findings for ensuing chapters. Patton (2002, p.467) argues that such 'qualitative findings are judged by their *substantive significance*' and that this can be assessed against criteria such as:

[87] Hemming (2008, p.155) discusses how others prefer the term 'crystallisation', to reflect that there are more than three perspectives on a situation and to signify 'that mixing methods can only produce a deeper and more complex view of the issue under investigation, rather than improve validity.'

- The extent to which the evidence supports the findings (in terms of its solidity, coherence and consistency);
- The extent and manner in which findings contribute to an understanding of the studied subject;
- The extent to which findings are in line with current knowledge. Here Patton (2002, p.467) distinguishes between 'confirmatory significance', where a finding is 'supported by and supportive of other work', and 'discovery or innovative significance', where a finding 'breaks new ground';
- The extent to which findings are of relevance for a particular purpose (such as theory development or policy refinement and formulation) (Patton, 2002).

Prior to a discussion of the findings in the ensuing chapters, Section 5.6 provides information on the research participants and their LZC technology.

5.6 Research participants

5.6.1 Response rate

Questionnaires were distributed to 947 households (Section 5.3). Through door-step conversations and comments on returned but uncompleted questionnaires, it became apparent that not all targeted households had LZC technology; stated reasons or derived explanations for this varied as exemplified in Appendix 21. With this collated information, a more accurate number for those developments likely to have LZC technology was established. The picture was complicated by the fact that at least a few residents did not realise they had such a technology installed, as became apparent via door-step conversations and returned questionnaires. In certain instances, for example, householders were aware of equipment in their loft but did not realise it was a MVHR system, mistaking it for an air-conditioning unit or simple extractor fan. Out of the initial 947 households contacted, a maximum of 717 were subsequently deemed to potentially have LZC technology.

122 householders participated in the survey. Taking the revised estimate of the target population as 717, this represents a 17% response rate[88,89]. Within the research literature, the response rates obtained for household surveys vary considerably for energy-related studies.

[88] Response rate = [(number of respondents) ∕ (number of eligible respondents)] x 100
[89] For unsolicited mail-based surveys, where no incentives for completion are given and one mailing is sent, a response rate no greater than 20% is expected (Bourque & Fielder, 1995).

For example, one postal survey requesting the completion of a lengthy questionnaire achieved a 5% response rate (Guerra-Santin & Itard, 2010), whilst a survey conducted through personal contacts, where the questionnaire was both distributed and collected by hand, achieved a response rate of 66% (Mansouri-Azar, 1996).

Within returned questionnaires, different questions were sometimes left unanswered intentionally or unintentionally[90], leading to what is termed item non-response bias (Fink, 1995). In the graphs that are presented in this thesis, the number of responses on which each graph is based is stated (by n=x) in order to reflect this variation in response numbers.

5.6.2 Characterisation of research participants

This section summarises the survey data that contributes to a description of the research participants, their household composition and the size and age of their home. The survey participants and interviewees are considered in turn.

Characterisation of survey participants

The age distribution of survey participants (Figure 5.2) fell quite evenly across the 26 to 55 year age band, with a reduced but even distribution across the 56 to 66+ year age band. The least represented age category was 18-25 years.

With regards to the gender of participants, 59% of all survey respondents were male (Figure 5.3). When considering only joint households[91] (n=80), 59% of respondents were again male and 41% female. A potential reason for this differential was proposed in Section 5.5.1 and the potential impact that this differential may have on how the questionnaire was completed is explored in Section 9.2.4.

The dwelling type in which survey participants lived is illustrated in Figure 5.4. Flats or maisonettes are the predominant built form (46%), with the remaining dwellings spread relatively evenly across the terraced, semi-detached and detached categories. As regards the size of the survey participants' homes, two-bedroomed dwellings constitute the mode and 2.9 bedrooms the arithmetic mean (Figure 5.6).

[90] Established during interview discussions
[91] Comprised of at least two adults

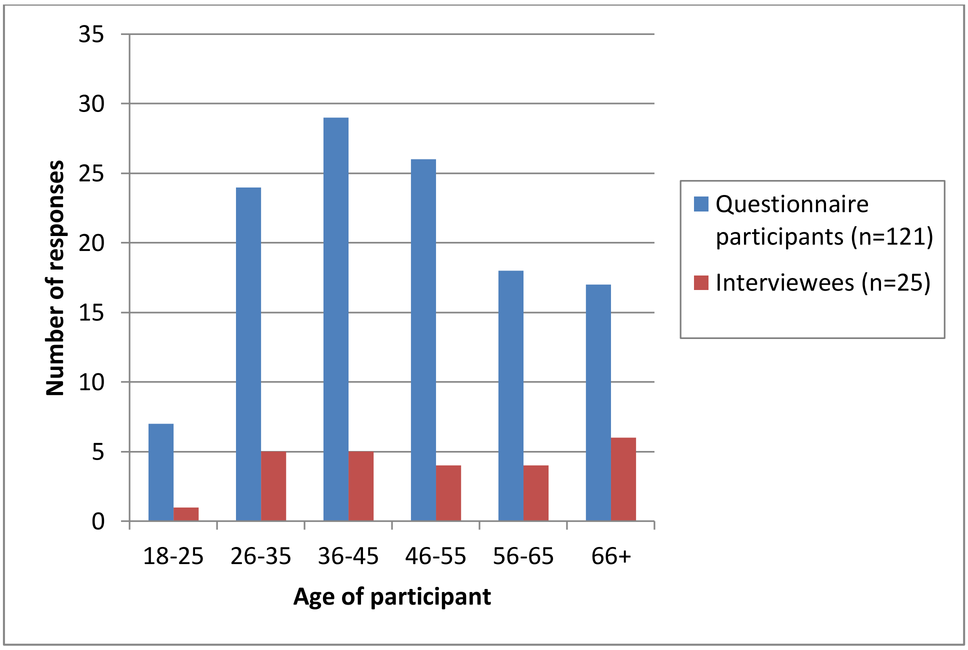

Figure 5.2. Age of research participants

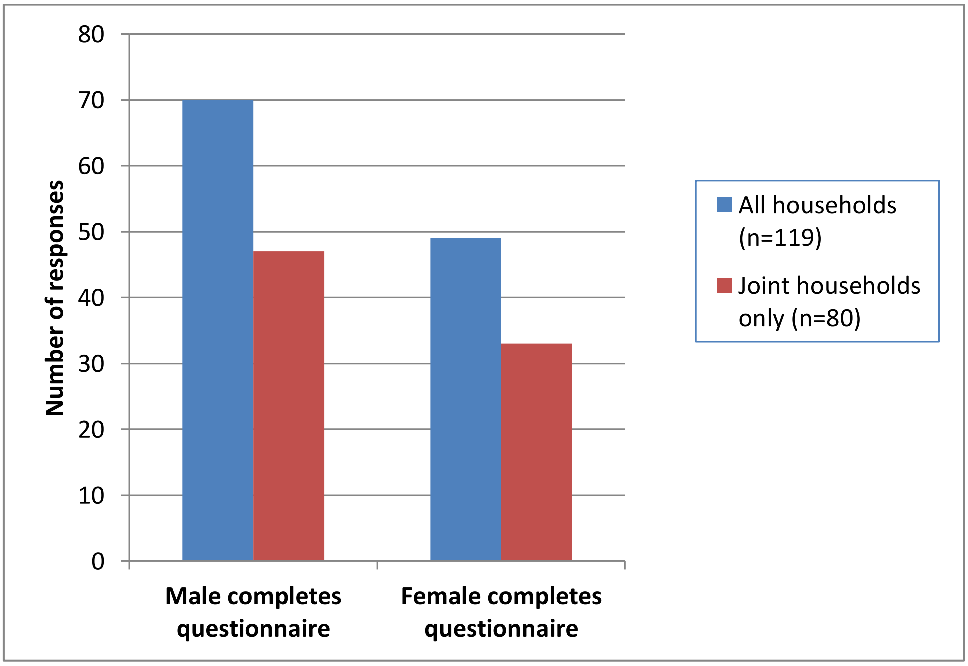

Figure 5.3. Gender of survey participants

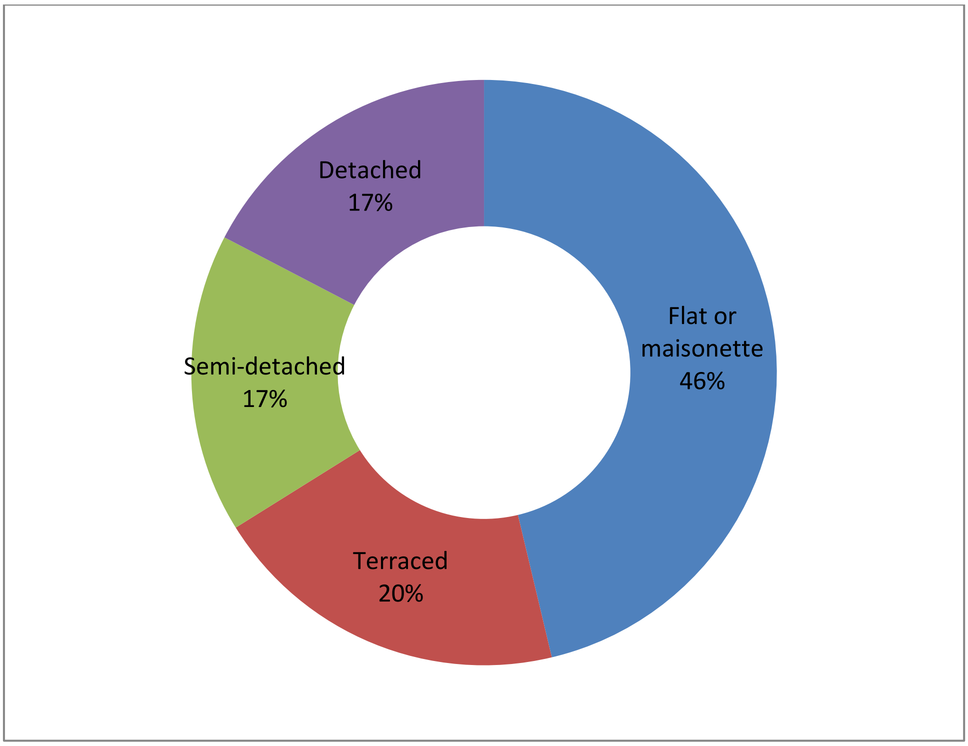

Figure 5.4. Dwelling type for survey participants (n = 121)

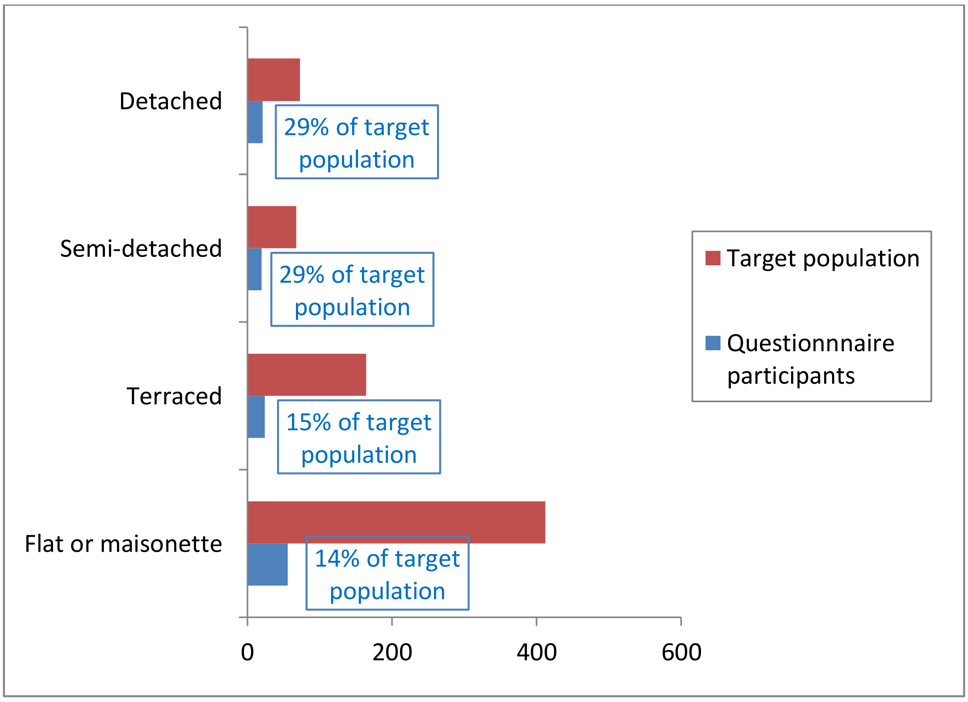

Figure 5.5. Comparative occurrence of dwelling type between survey participants and target population

Figure 5.5 illustrates the degree to which the distribution of respondents' dwelling types is representative of the target population as surveyed[92] and it indicates that occupants of flats and terraces are slightly under-represented compared to occupants in semi-detached and detached properties, which are over-represented. As noted in Section 5.5.1, it is difficult to assess whether and how the non-representativeness of the survey respondents in these regards may impact on the reliability of the research findings.

The type of tenancy held by participating households in the survey is summarised in Figure 5.7. The majority of households live in privately-owned or privately rented accommodation with 11%[93] residing in social housing (comprised of rented housing association accommodation or shared ownership arrangements with a housing association). This distribution between private and social housing appears relatively representative of the wider target population surveyed, where social housing is estimated as constituting 14% of the tenancy mix[94]. 18% of all participating households lived in rented accommodation (covering private and housing association rentals). This proportion is less than that quoted for the UK population as a whole within all ages of housing (i.e. 30% (NHBC Foundation, 2012b)), but comparative data relating specifically to new housing has not been found. The influence of renting versus home ownership on whether householders turn to neighbours for technology-related information is explored in Section 9.3.2.

72% of participants had lived in their homes for less than two years at the time of the survey (Figure 5.8). This was perceived as beneficial as it was considered that issues relating to installed LZC technologies, even if now altered or resolved, would still be readily recounted.

[92] The dwelling types associated with each household within the target population as surveyed was collated using data from WBC's 'Completed permissions' database, my own database compiled from returned questionnaires and field observations.
[93] This figure of 11% is more accurate than the 12% figure that would be derived from Figure 5.7 due to the rounding-off process used in the latter.
[94] The tenancy types associated with each household (or development) within the target population as surveyed was collated using data from WBC's 'Completed permissions' database, my own database compiled from returned questionnaires and door-step conversations.

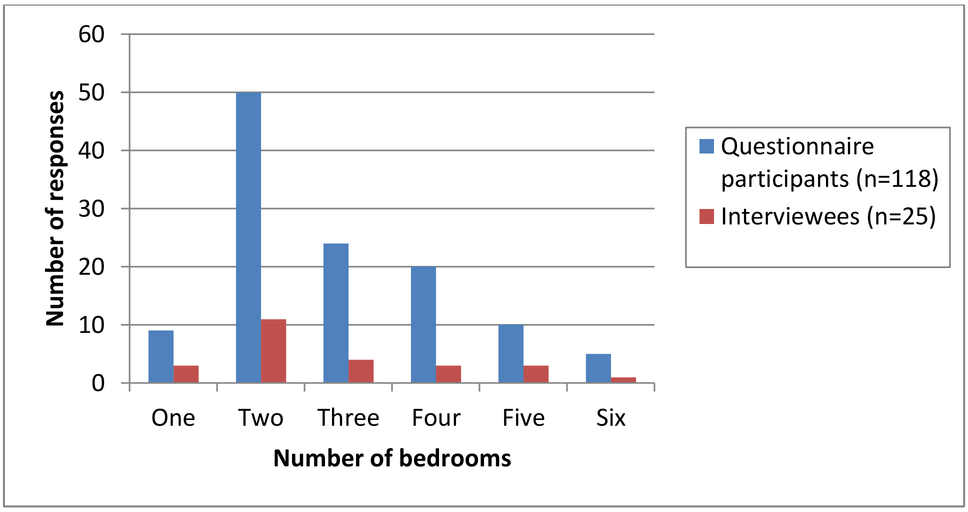

Figure 5.6. Number of bedrooms in research participants' homes

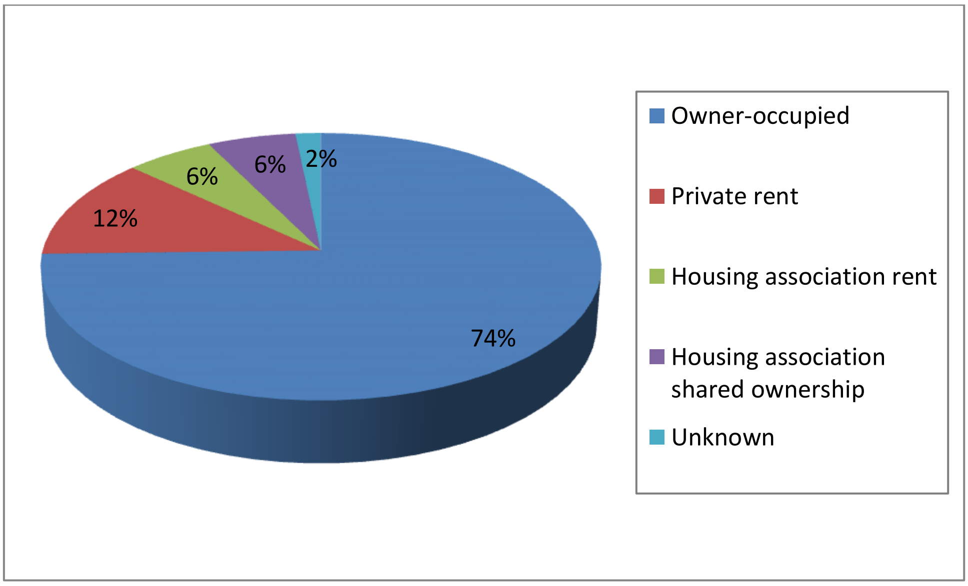

Figure 5.7. Tenancy type held by survey participants (n=122)

The combined household income distribution (Figure 5.9) shows that 47% of households participating in the questionnaire survey earned more than £60,000 per annum. 33% of survey participants had children living at home and 31% consisted of single adult households.

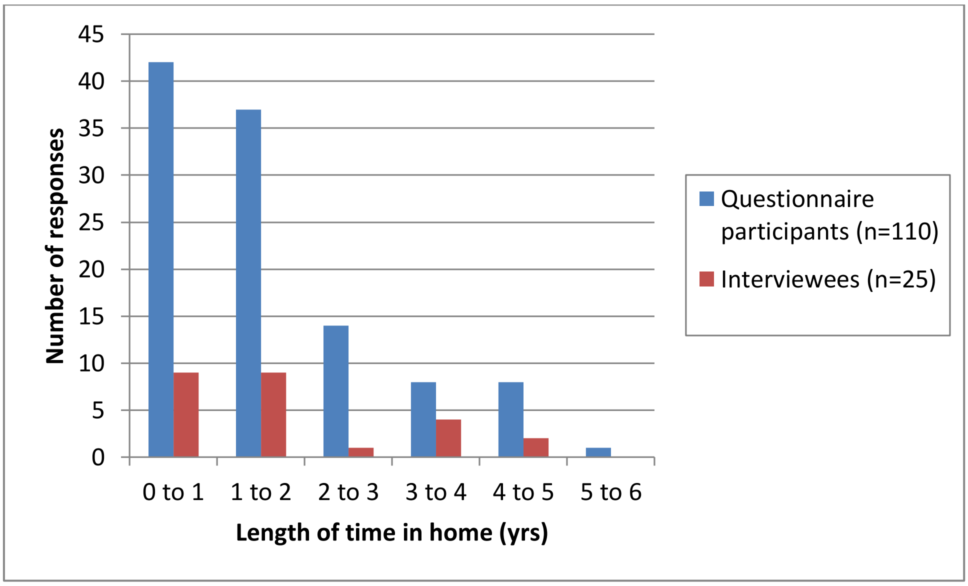

Figure 5.8. Length of time research participants have lived in their homes

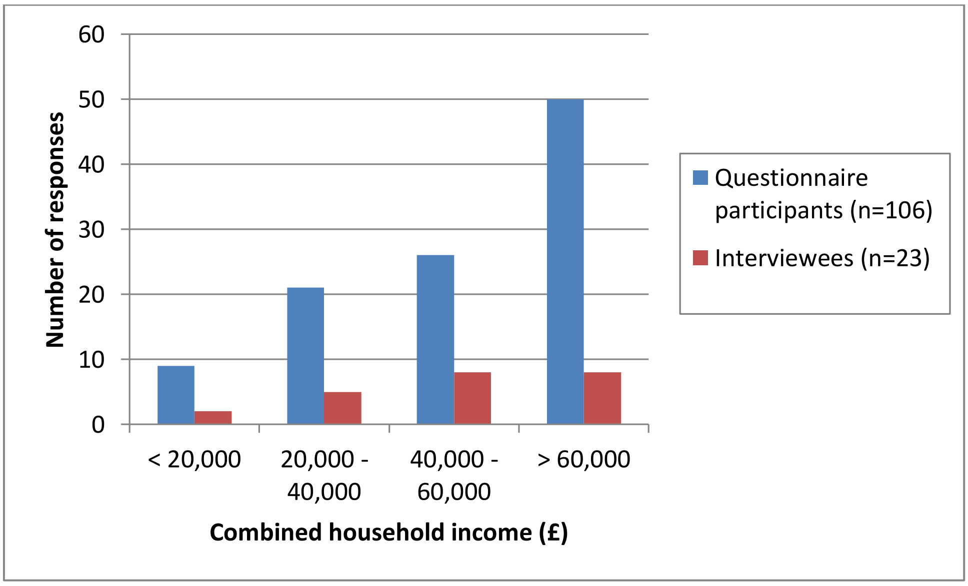

Figure 5.9. Combined household income

Characterisation of interviewees

It is of interest to see how the characteristics of the interviewees compare to that of the surveyed group. The interviewees were comprised of thirteen men, eleven women and three mixed couples. Their age distribution is similar to that of the questionnaire participants (Figure 5.2) except for the 66+ category, which is over-represented by the interviewees. This is not unexpected as people falling within this age range were retired and were therefore likely to have had fewer demands on their time, enabling them to more readily participate in the research.

The interviewees' tenancy type is illustrated in Figure 5.10; compared with Figure 5.7, it can be seen that 10% more interviewees than questionnaire participants lived in owner-occupied properties, and no interviewees lived in homes rented from a housing association. As regards the size of the interviewees' homes, two-bedroomed dwellings constituted the mode and 2.8 bedrooms the arithmetic mean; very similar to the case for the questionnaire participants.

As summarised in Figure 5.8, 72% of interviewees had been in their homes for less than two years at the time of the questionnaire survey, which was the same percentage derived for the questionnaire participants.

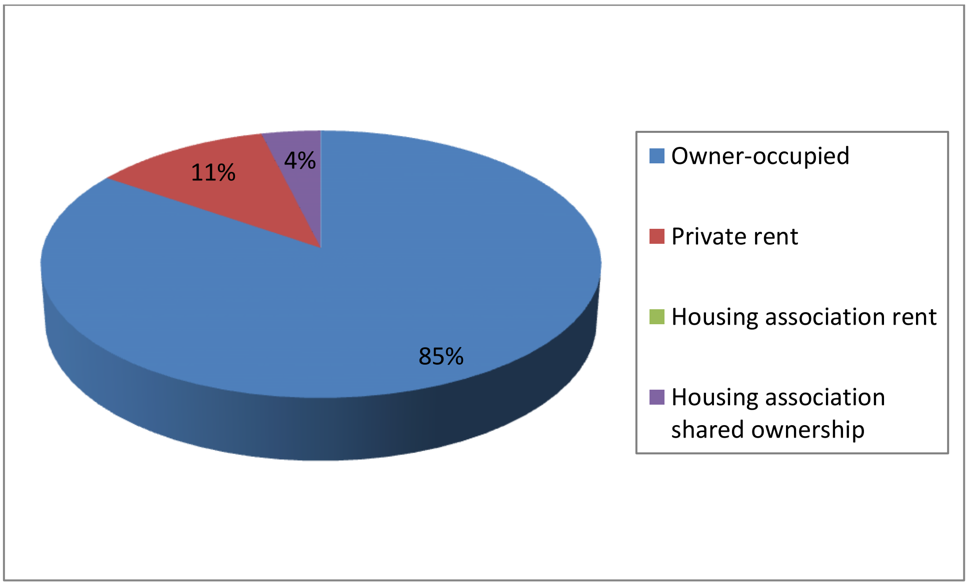

Figure 5.10. Tenancy type held by interviewees (n=26)

29% of interviewees had children living at home (similar to the 33% figure for questionnaire participants) and 44% consisted of single adult households (13% higher than the figure for questionnaire participants). The combined household income distribution for interviewees shows a more even distribution then that that exhibited by the questionnaire participants (Figure 5.9).

5.6.3 LZC technology installed

This section reveals what LZC technologies developers have selected to comply with the Merton Rule-type planning policy.

The technology that survey respondents identified as being installed is summarised in Figure 5.11. STHW systems are the predominant technology, present in 62% of homes. The next four most commonly installed are CHP, ASHP, MVHR and communal biomass systems, each present in 12%-16% of households. 26 of the 122 participating households had more than one technology. Certain householders were confused as to the type of technology installed; for example, one interviewee mistakenly stated on their questionnaire that they had a PV system, but through discussions it became apparent they had a STHW system. Thus, it is expected that a proportion of survey respondents will misidentify installed technology or mistakenly state they have none. This introduces an unquantifiable degree of error into Figure 5.11.

The distribution of the various LZC technology types amongst the interviewees mirrored quite closely the distribution seen overall for survey participants, apart from a higher proportionate presence of PV installations (see Figure 5.11).

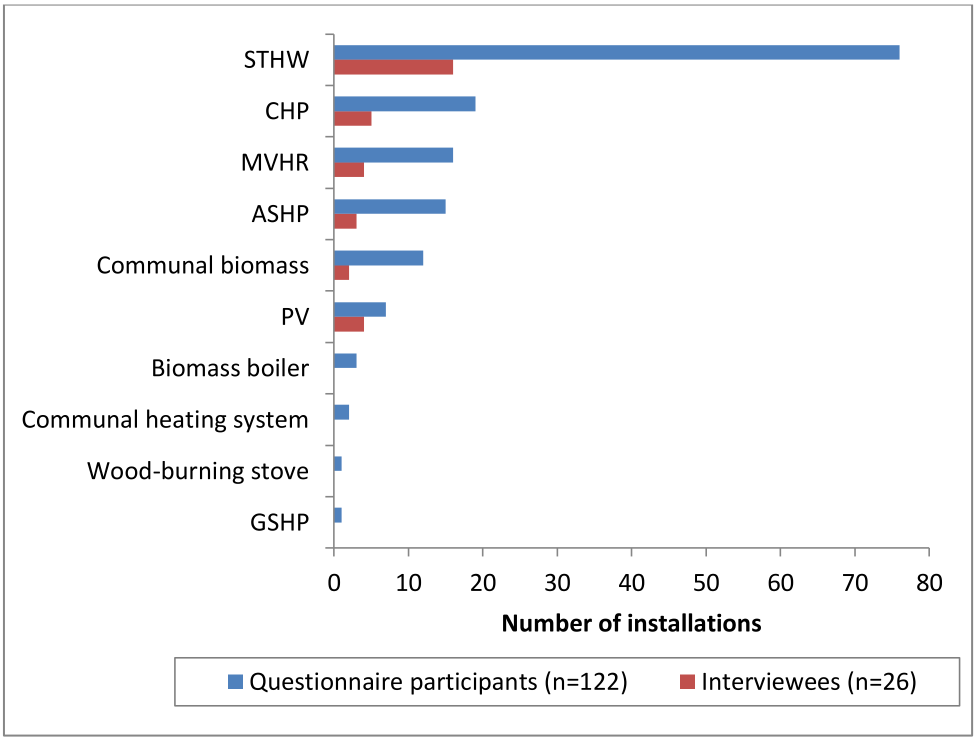

Figure 5.11. Which LZC technologies are installed?

WBC does not collate comprehensive information on LZC technology types proposed in planning applications or present in completed builds. There is a relevant field included in their 'Completed permissions' database, but data entry is incomplete and the entered data is not deemed reliable[95]. Thus, there is no reference data with which to assess the representativeness of Figure 5.11 against all new builds across the borough.

A recent survey of the UK house-building sector (NHBC Foundation, 2012d; Lees & Sexton, 2014) also indicated that STHW systems were the most used LZC technology, though PV systems were reported as coming second which is at variance with this research's findings (Figure 5.11). However, the basis of the NHBC Foundation's (2012d) research differed in that it focused on the range of technology *types* used by various developers, as opposed to the *number* of installations of each type installed by them. The findings from this research provide an indication of which LZC technologies will be predominantly selected by developers to comply with increasingly stringent Building Regulations (Sections 2.3 and 3.8) and this contributes to current knowledge in this area.

In this chapter, I have provided an account of how the research was conducted and how the eventual research trajectory emerged out of that envisaged. The next chapter constitutes the first of four chapters within which the research results are presented and research findings derived.

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[95] As communicated by the Planning Policy Officer and confirmed by cross-referencing between their database and my own, as compiled from completed questionnaires.

Chapter 6: Moving in with LZC technology

6.1 Introduction

Having detailed how the research was undertaken in the last chapter, I proceed in this chapter to present the first tranche of research findings, which pertain to the embryonic LZC technology-householder association. Four elements to this, as encompassed by the appropriation component of domestication, are discussed. I start by considering the degree to which LZC technology is actively appropriated, in that it constitutes a desirable, known feature of the home; the findings contribute to a better understanding of the technology's agency within mainstream UK housing (Section 6.2).

In Section 6.3, I evaluate the adequacy of documentation on LZC technology as provided by housing industry representatives and find that householders' views on this are polarised. I then broaden the discussion to consider the extent to which householders receive verbal instructions and visual demonstrations from housing industry representatives, illustrating how this influences the development of LZC technology-householder associations (Section 6.4). Lastly, I provide a limited insight into the level of information and experiential knowledge imparted by departing residents to newcomers (Section 6.5). I find that the re-domestication process may start out from a less-informed set of socio-technical relations. The main findings from the chapter are summarised in Section 6.6.

Through the discussion, the following four research questions are addressed: *to what degree are LZC technologies actively appropriated in new dwellings (Section 6.2); what are householders' perceptions of the documentation provided for LZC technology (Section 6.3); what verbal instruction on LZC technology is provided on moving in (Section 6.4); and, what knowledge do departing residents impart to new users of LZC technology (Section 6.5)?*

6.2 To what degree are LZC technologies actively appropriated?

In this section, I explore the degree to which LZC technology is actively appropriated by householders during the home selection process, as opposed to it just constituting a known or unknown feature immaterial to decision-making. This constitutes an under-researched topic for homes built to Merton-Rule type policies; particularly low energy housing has received more attention in this context (see Mlecnik, et al. (2012), for example).

In this research, surveyed householders (n=122) were asked whether the presence of LZC technology had positively influenced their home's selection; 39% agreed or strongly agreed that it had (Figure 6.1):

> 'My son works for *[the developer],* and that's how we knew about these flats and he was able to tell us that if you have a flat on the top floor, then you will have these solar panels.' (ID94, STHW)

> 'My husband and I bought our flat off plan in 2008, taking into consideration a number of features the developer promoted in relation to low energy technologies, including the provision of a biomass boiler …' (ID786, CHP & communal biomass)

Some of these describe how LZC technologies were perceived as providing financial and/or environmental benefits:

> 'We were hoping it would save us money in the long-run.' (ID94, STHW)

> '… we were told in fairly positive terms that it was going to be an eco-friendly, carbon reducing, low cost, low energy, renewable source energy system which would provide electricity and hot water to the flats, and that was something we were quite interested in.' (ID786, CHP & communal biomass)

For this 39%, the technology represented a feature which actively contributed to the home's appeal; in other words, the technology had demonstrated agency within the home selection process via its perceived financial and environmental attributes, for example. Seemingly similar results were obtained by Mlecnik et al.'s (2012) survey in Germany and Austria, wherein 33% of 90 households in particularly low energy homes stated that solar energy usage was an important factor in home selection.

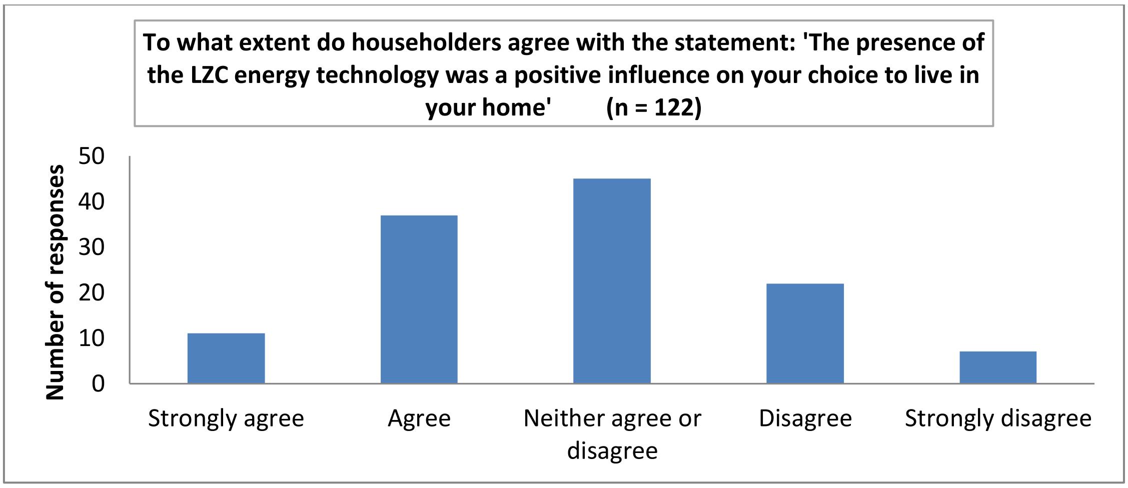

Figure 6.1. The influence of LZC technology on the home selection process

A further 37% of surveyed householders (Figure 6.1) neither agreed nor disagreed that the technology positively influenced their home's selection. Some of these bought or rented their property without any initial awareness of the technology:

> 'When we first saw the house, we thought, because it looked like an air conditioning unit, we thought maybe we've got heating and air conditioning. And when our friend went to see it, she said 'I know what that is, it's an *[ASHP]*.' (ID817, ASHP)
>
> 'They were finished, so I didn't sort of ask for the specification. I went, looked at them and bought.' 'I didn't even know *[the STHW system]* was there.' (ID273, STHW)

Others viewed their future home without knowing about the technology in advance, but then became aware of it during the on-going sales/renting process. For these, the technology starts off as an unexpected feature and their initial relationship to it ranges from being quite dispassionate to being mildly interested:

> '… they just said - 'Oh, by the way it's got *[a STHW system].'* It was an extra thing - 'All right, okay.' It was one of the things that sort of pushed me that way but I didn't go actively looking for it.' (ID155, STHW)
>
> 'It was just sort of we love the house and the location. And we were kind of intrigued by the panels, I think. I remember as a child holidaying in Greece a lot and sort of saying they always had solar panels to heat their water. And I remember thinking, it's not that sunny in Woking, I don't see this is going to be particularly effective. I have to say, being quite sceptical, but remember thinking, oh well, never mind it will be something – if it works it will be great ...' (ID1030, STHW)
>
> 'I was interested, you know - 'Oh right', I'd not come across it before.' (ID1056, ASHP)
>
> 'Although I am interested in LZC to save money and polar bears, the flat comes with district heating – it wasn't a factor in my decision.' (ID526, CHP)

The remaining 24% of householders disagreed or strongly disagreed that the technology positively influenced their home's selection. Some of these were seeking rather to live in new homes because of their expected energy efficiency:

> '… we did not buy the apartment for its propensity to save the world from greenhouse gases but rather to save ourselves from huge bills. Our motives were and remain wholly selfish.' 'We were sold it on the basis that it was extremely energy efficient.' (ID804, CHP & communal biomass)

For others, there were overriding priorities within their lives which placed the LZC technology 'beyond domestication' (Carter, Green, & Thorogood, 2013, p. 352) over and above its physical presence and autonomous functioning. The first example below relates to a 96 year-old flat owner within an extra-care establishment, and the second is of someone uninterested in the technology's financial or environmental benefits:

> 'I've filled this in on behalf of my elderly mother. Although I am very committed to LZC energy, it of course is of necessity way down the list of issues relating to my mother.' (ID92, STHW)

> 'I have an excellent understanding of engineering, computing and other technology. However, I am not in the slightest bit interested in how my home is heated, nor the associated costs of electricity, as I have too many other things going on in my life.' (ID709, PV & STHW)

This category also included someone who was unaware of the technology installed:

> 'Until I received this questionnaire, I was not aware of the LZC in my house. I do care about the environment, but have not read through the literature provided by my landlord - I rent the property.' (ID907, STHW - roof integrated)[96]

The degree to which LZC technology can contribute to a home's appeal will be influenced by the extent to which information on it forms part of the marketing material and sales pitch from the developer, agent or landlord (that is, the extent to which it is incorporated into the written and verbal 'sociotechnical script' (Faulkner, 1998, p. 487) as presented). For the 39% of cases where the technology positively influenced the selection process, adequate upfront information must have been provided for this to have occurred; in other words, the technology's presence had been made evident through the circulation of written or verbal information, which enabled the active appropriation of the technology as a desirable component of the home. However, comments made by some of the 37% who neither agreed nor disagreed that the technology influenced their selection process, suggest that a proportion of them had not received (or, if received, had not read) sufficient information on the technology early enough for its presence to have significantly influenced decision-making. In some of these cases then, it appears that developers omitted to initially circulate technology-related information, thwarting the technology's potential agency in the home selection process and postponing the initiation of LZC technology-householder associations. For the remainder of this 37% who knew about the technology, it did not exhibit any significant agency within the home selection process.

The extent to which LZC technology is drawn attention to by housing industry representatives may reflect their confidence that it adds to, rather than detracts from, a home's marketability, which is mainly driven by price, size and location (DCLG, 2007d). Developers in this study have installed LZC technology to comply with local planning policy (except one development built to Level 5 of the CSH); the fact that these installations have been policy-driven as opposed to

[96] One interviewee was the chairperson of the Management Committee for this development. He confirmed that all the houses had a roof-integrated STHW system.

market-driven may affect the focus placed on them within marketing literature and sales pitches. A recent study of five households indicated the marketing of LZC technology in mainstream UK housing is low key (NHBC Foundation, 2012d); in a further study of developers' sales teams, only three out of six viewed LZC technology as a 'sales feature' and information relating to the 'benefits and limitations' of installed LZC technology were not provided to potential buyers early on (NHBC Foundation, 2013b, p. 15). These findings are in line with more general research on estate agent's on-line marketing for homes in the UK, where it was found that information on energy costs, energy savings and sustainability issues were typically absent or 'externalized' and did not contribute to the ways in which the dwellings were framed at this early stage (Aune, 2012, p. 720)[97].

As highlighted in Section 3.6, research on the degree to which LZC technologies are actively appropriated as part of the selection of otherwise conventional homes, that are not highly sustainable (eco-homes) or particularly low energy (such as passive homes), is scant and restricted to a number of small-scale studies. In one 12-unit UK development with PV systems, the technology was 'not a factor' for householders when purchasing their home (Ghanem, 2008, p. 159), a finding mirrored in a study on six new homes fitted with LZC technology (NHBC Foundation, 2013b). In another study of five UK homes, householders were typically unaware of the technology prior to purchase and most did not consider the home's environmental performance a key factor (NHBC Foundation, 2012d). From the perspective of developers and property sales, one study of UK developments incorporating PV systems found that: 'there seemed to be no indication that the properties were sold or occupied more readily because of the PV' (Munzinger, et al., 2006, p. 65).

This research extends current knowledge in this area and, as it is based on a significantly larger data set (n=122) than previous relevant studies involving householders, the results can be considered more representative. The finding that 39% of survey respondents viewed the technology as positively contributing to the home selection process contradicts these previous UK studies that have concluded that LZC technology has minimal agency within the selection process for otherwise mainstream housing.

[97] Article 12 of the EPBD Directive (European Parliament, 2010a) requires the inclusion of energy performance information in commercial media advertising of properties from 2013, which may alter this situation.

6.3 What level of documentation is provided when moving in?

In this section, I consider what level of information on LZC technology is provided and how this shapes embryonic technology-householder associations. Surveyed householders were asked how much they agreed or disagreed with the statement: 'The developer or landlord has provided you with sufficient information on operating and maintaining your LZC technology.' The distribution of responses paints a polarised state of affairs (Figure 6.2); 42% agreed or strongly agreed with the statement, whilst 46% disagreed or strongly disagreed. Only 12 % took the middle ground of neither agreeing nor disagreeing. This polarised distribution of

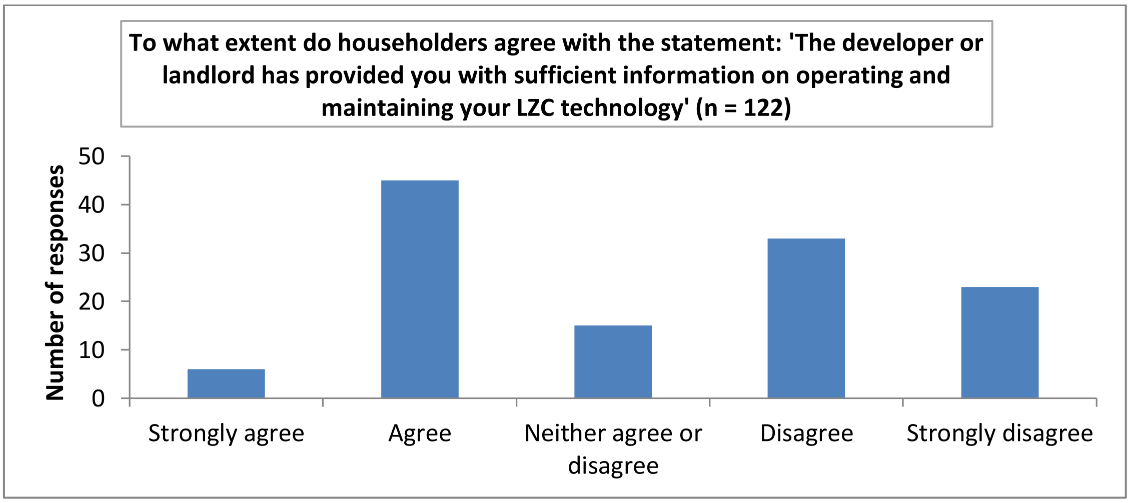

Figure 6.2. The adequacy of information on LZC technology from developers and landlords

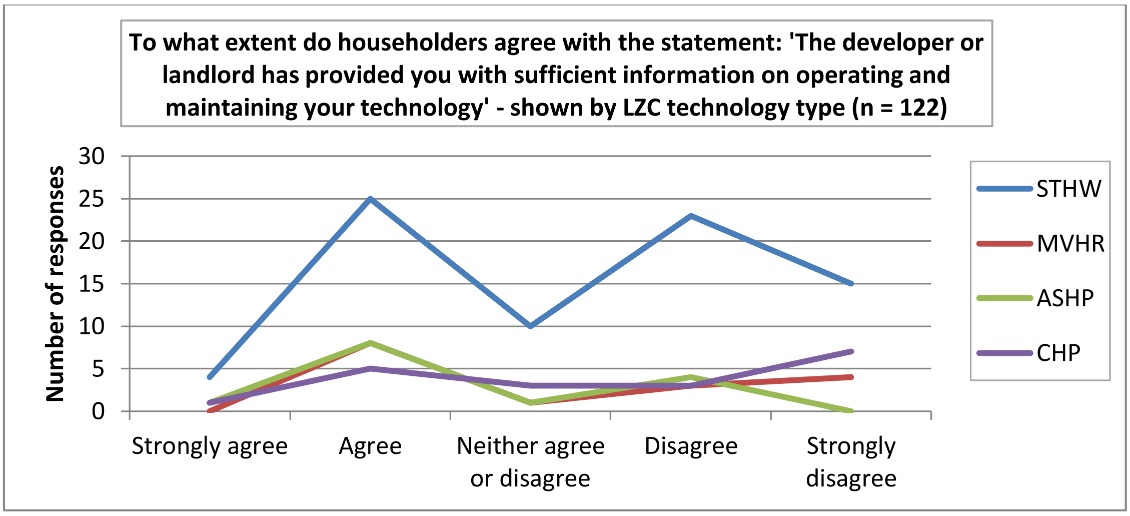

Figure 6.3. The adequacy of information on LZC technology from developers and landlords – by technology type

responses is maintained for the predominant technology types (STHW, ASHP, MVHR[98] and CHP) (Figure 6.3) and holds also across tenancy types (owner-occupiers and renting tenants) (Figure 6.4).

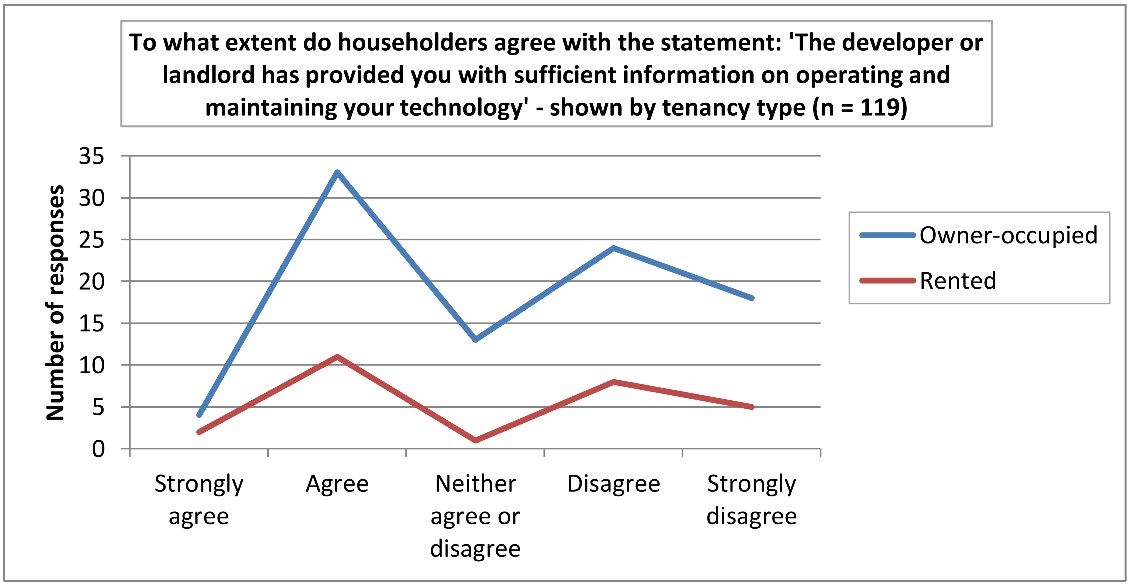

Figure 6.4. The adequacy of information on LZC technology from developers and landlords – by tenancy type

Elsewhere, research on 546 active UK *retrofitters* of LZC technology (mainly STHW systems) found that 64% were satisfied with operating instructions received (Caird & Roy, 2010). This is noticeably higher than the 42% of satisfied householders observed in this research. However, householders who actively install technology will have a direct association with installers, through which relevant information can transfer. In contrast, occupiers of pre-fitted homes would not generally have direct contact with installers, and would be liaising instead with developers. Where developers receive instructions from installers but withhold these from occupants, they cannot be viewed as aligned intermediaries[99] who effectively translate instructions from installers to householders. Instead, they may hinder the enrolment of householders into the technology's socio-technical network and thereby reduce the technology's agency (at least initially).

[98] Interestingly, the NHBC Foundation (2013a) also reported a polarised distribution of responses when householders in ten MVHR-fitted new homes (built to CSH Level 6) were asked, firstly, whether they understood how to control their heating and, secondly, how easy they found it to use these systems.
[99] If an entity receives a circulating entity (e.g. instructions) and passes it on without changing it, or being changed through this process of translation, that initial entity is termed an intermediary (Latour, 2005). Intermediaries can include inanimate objects such as machines or monitoring systems, but also 'disciplined human bodies' (Callon, 1991, p. 134).

Previous studies on those moving into mainstream UK housing fitted with LZC technology have commented on the technology-related information provided. One large scale study on PV-fitted homes commented on the potential inadequacy of information provision but did not quantify the prevalence of this (Munzinger, et al., 2006). Other studies have been relatively small-scale; some conclude that information provision has been inadequate (NHBC Foundation, 2012b (five households); BRE, 2008 (six households); NHBC Foundation, 2013b (6 households)) but another study on a 12-unit development found that PV information packs had been provided by the developer (Ghanem, 2008). In Monahan's (2013) study on a 15-unit social housing development tenant packs had been provided, but the information was generally considered technical and geared at commissioning. Larger-scale, multi-development studies (such as this research provides) that assess the adequacy of information provision have not been found.

I further explored the nature and perceived adequacy of the technology-related information provided with interviewees, both in terms of documentation and verbal and visual instructions (discussed separately in Section 6.4); the remainder of this section focuses on written material. Those interviewees that agreed or strongly agreed in the survey that information provision was adequate can be ascribed to one of three categories, based on their use of or more detailed view on the documentation. The first category contains those that have not consulted the documentation:

> 'They gave us a very good book – I've never looked at the book but it had all the service manuals in there when I bought the flat, but I'm not the sort of person who looks at them.' (ID273, STHW)
>
> 'Do you know, I don't think I would be able to find the bloody manual.' (ID826, STHW)
>
> '… this is the first time I've actually opened the manual. It just went into a pile with everything else when we moved in.' (ID928, STHW)

This last quote came from a householder who had lived with his STHW system for four years without referring to the documentation. It could be argued that these householders' views on the adequacy of the documentation is not grounded in its readability or usefulness, as it has neither been read nor used to guide interactions with the technology.

The second category of those that stated in the questionnaire that received information was adequate is comprised of those that proceeded to provide a less favourable account when interviewed:

> ‘There was a bit of information … But actually that is quite sparsely written.’ (ID 155, STHW)

> ‘The instruction manual just tells you how to turn it on. It tells you how to turn it on; it tells you what the little meter inside means, that’s all.’ (ID829, STHW)

> ‘… we’ve all found the programmer and the manual that goes with it all a little bit difficult to find how to do what ... I think it’s quite complicated and I think it’s badly organised, in the sense that it goes into too much detail on certain things and so you just go ‘No, I need to know this answer’ and you can’t find it.’ (ID1023, ASHP)

The third category of householder appears genuinely satisfied with information provided:

> ‘It was quite descriptive … I read through and it was very simple to understand the instructions you know. I just played around a bit, saw how it sort of worked ...’ (ID640, CHP)

> ‘*[For]* the MVHR … we were given some information in the sort of home owners pack that *[the developer]* gives you when you take over the property… It is ages since I read it. It’s quite theoretical about how the thing is supposed to work …. The only information we were given on how you operate it was that in the summer you put it on to the blue side of the dial and in the winter you put it on to the red side. That’s it. So that’s all I do, switch it backwards and forwards.’ (ID424, MVHR & STHW)

Only two of the interviewees adopted a neutral stance within their questionnaire on the adequacy of the technology-related information. Those that considered the information inadequate identified one of three main reasons for this, the first being that it was too complicated or badly written[100]:

> ‘Well, they had a guide to what the buttons did, which we kept, on the panel, but then there was a book we had given when we moved in. It actually showed you how to install the whole thing, if you wanted to. I think it’s what they used to install it and they just put it as part of the book. It had ‘Connect it to this, do this, do that ... You would need to be an electrician or specialist to understand it…. Also, it was already installed so why did I need a diagram on how to install it, kind of thing. It was very unusual.’ (ID295, STHW)

> ‘The manual that goes with *[the ASHP]* really is very, very unclear… Now, I’m used to reading instructions booklets because I was a science technician, [...] and I’ve tried several, several times and ‘What do they mean?’’ (ID1056, ASHP)

The second reason, given by three interviewees living in the same development, was that information provided when purchasing the property had been misleading, both with respect to the role of the three communal energy systems present and with regards to the level of service charges that would be levied on residents for the operation and maintenance of these:

[100] Householders also find gas central heating manuals hard to understand (NHBC Foundation, 2012c).

> ‘Part of the issue is that the information that we have been provided with from when we first ever came to look at the development through to purchasing, then following our complaints *[to the developer, local authority and management company]* - there seems to be a lot of misinformation, and a lot of contradictory information … And then in respect to the further questions about the cost of the service charges and so on, kind of lack of information.’ (ID786, communal biomass & CHP)

> ‘There is a lot of disheartened people when we talk about *[the developer]* … some were even quoting that we were mis-sold *[the properties]* because we were given wrong information.’ (ID805, communal biomass, CHP & MVHR)

The third reason given was that insufficient documentation had been provided:

> ‘I had to really badger the builder to actually find out how it all worked… *[The developer]* who built this, their little slogan is ‘greener by design’, so they are very much: ‘We want to be a green builder’. But actually, although they installed the solar panels, they actually never told us how they worked, they didn’t do anything about it; they just left us… there wasn’t any instruction … And so yes, it’s completely ridiculous; the builders paid, installed these things and then just left them.’ (ID1030, STHW)

The lack of any written information was also highlighted by the following comment made on a returned questionnaire:

> ‘Solar panels were provided with the house - we have been given no documentation for the system!!’ (ID732, STHW)

I additionally asked interviewees with STHW systems whether the documentation recommended any measures to take to optimise the benefits gained from the technology. Such measures would include reducing dependence on conventional water heating systems and changing the timing of hot water demands to optimise the household’s use of solar-heated water. No-one could remember their documentation recommending any such behavioural changes.

To summarise, those interviewees that stated within the questionnaire that adequate information had been provided on the operation and maintenance of their LZC technology can be assigned to one of three categories. The first includes those that have received but not consulted such information (a finding observed elsewhere (Ghanem, 2008; NHBC Foundation, 2012c)); consequently, their views on the adequacy of the documentation are not grounded in its readability or usefulness, as they have not referred to this aspect of the technology’s distributed inscription (Section 3.4). Instead, their judgement appears based on the knowledge that they have the documentation stored somewhere, though any interactions with the technology have not been actively shaped by it. The second category includes those who stated in the questionnaire that the information provided was adequate but then proceeded to provide a less favourable account of it when interviewed, describing it as sparsely written or complicated, for example. Here, the documentation did not adequately meet householders' needs. The third category appears genuinely satisfied with the documentation, which has been read and has helped shape technology-householder associations. Here, the documentation forms an effective part of the technology's *formal* distributed inscription (Section 3.4). Those that considered inadequate information had been provided were not just referring to the potential absence of sufficient information; in certain instances, householders were referring to documentation which was either incomprehensible or deemed to be misrepresentative of actual arrangements.

6.4 What verbal instruction is provided when moving in?

So far, the discussion on the (in)adequacy of information has centred on the written word. In this section, I broaden the discussion to consider the extent to which householders receive verbal instructions and visual demonstrations pertinent to their LZC technology from housing industry representatives. I view such advice as being part of the *informal* distributed inscription (Section 3.4) pertaining to the technology, in that it is external to the set of devices, such as instruction manuals and control units, designed to impart relevant information. The impact of these verbal and visual instructions (or their absence) on embryonic LZC technology-householder associations will be considered. The content of conversations householders subsequently have with other residents and with those that come to repair or maintain their technology (also both part of the *informal* distributed inscription) are discussed separately in Sections 9.2 and 8.2 respectively.

Out of the 26 interviewees, 11 had not received any verbal instructions on their technology, whether from housing industry representatives or previous occupants (pertinent in two cases). In one instance, an explanation of the technology had been promised:

> '… they actually said in their information at some stage you will have a meeting with the site manager who'll explain everything to you. We didn't really have a meeting like that at all – he really wanted to avoid us more than anything.' (ID804, CHP, communal biomass & MVHR)

In another of these 11 cases, the new home was being rented from a housing company owned by the local authority. This household received no verbal instructions on their ASHP and in fact were not aware they had it until after moving in. This lack of input from housing industry representatives has been noted in other UK studies (NHBC Foundation, 2012c & 2012d).

15 out of the 26 interviewees, however, did receive some sort of introductory home tour that included verbal instructions relating to the technology. In certain instances, the verbal instructions were considered quite cursory:

> '… *[the developer]* just said 'it's going to provide about 10% of your energy' and then that was basically it.' (ID295, STHW]
>
> '*[The estate manager]* just said well: 'There are the switches and that's the booster switch', and that was about it.' (ID94, STHW)

With regards to STHW installations, no-one had been encouraged to switch off conventional water heating systems in summer-time, to test whether the STHW system was able to satisfy hot water demands on its own. Instead, the verbal advice generally advocated using conventional water heating systems throughout the year and most householders appeared shaped by this advice, trusting the way household energy systems had initially been set-up:

> '… all I see is a massive tank and a little electronic control panel at the side and we were told just not to mess with it unless there is a real emergency as it knows what it is doing … The verbal guidance was to leave it alone … all I had was a developer who said: 'Don't mess with it', and you don't go against that.' (ID833, STHW)
>
> 'one of the guys *[from the developers]* showing me round when I took the keys over – basically his recommendation was to run the electric heating, run the hot water heating for an hour in the morning, but then just see how it goes through the day. Solar thermal – I use it for all my hot water. I have the boiler come on for one hour first thing in the morning *[in summer-time]*.' (ID424, MVHR & STHW)

When this last interviewee was asked whether he had ever switched off the boiler in summer-time and tried relying solely on his STHW system, he stated:

> 'I haven't actually because it was recommended that I didn't.' (ID424, MVHR & STHW)

The following interviewee was also advised by the developer to rely on the conventional heating system year-round but was astute enough to realise this would not maximise her financial savings:

> 'I mean he said in the beginning: 'Oh you must have those two switches on', but I found by having these two switches that are on the wall, if you do have them on, then obviously, every night *[the immersion heater]* will come on and heat the water up, which is unnecessary.' (ID94, STHW)

These last few quotes, and the following two, illustrate a common theme running through the verbal advice, which was not to touch the technology:

> 'When I first moved in, I was shown around by *[the developer's]* site manager and the sales executives. And we walked upstairs, opened the airing cupboard door, and he said: 'This is your *[MVHR]* system – doesn't need touching, doesn't need altering.'… And I said: 'What's that?' and he said: 'That is not to be touched'' (ID805, communal biomass, CHP & MVHR)

> 'I was opening the windows and I had it on summer mode. Because we were told we were not allowed to switch it off, because it might get blocked or it might not work properly. So we were told to keep it on but open the windows.' (ID1154, MVHR & PV)

Evidence of this hands-off message has also been noted on a smaller scale by Dobbyn & Thomas (2005, p. 41) when interviewing three STHW households living in a UK housing association development; here, such communications were attributed with 'disempowering residents and making them feel they were not fully in charge of the technology'.

The last householder quoted (from this research) had a shared-ownership arrangement with a housing company, which might account for the high degree of involvement from the developer in setting out what the householder should and should not do. The householder described the developer who showed her around her home as 'very condescending, very patronising'. She goes on to describe the advice given:

> ''Don't touch this, don't touch that, oh, just leave that on that, if that light goes off then phone us or phone *[the maintenance contractor]*.' … he was talking to me as though I was stupid, but he wasn't actually explaining to me how these things worked ... I thought it was all very badly done actually, the way it was passed across to us. These houses where people don't really understand what they're about because there are so many new ideas in it.' (ID1154, MVHR & PV) *[occupant of a home built to Level 5 of the CSH]*

This desire to further understand LZC technology was reiterated by a number of householders who thought that more could be done by developers to facilitate a deeper understanding of the technology and, indeed, some thought they should have a responsibility to do so:

> '… it probably would have been quite useful to have had a bit of a training session.' (ID295, STHW)

> 'if they had told me what an evacuated tube was, how it operated and just sat down for a quarter of an hour, like this, and explained it … Of course it may be different if I'd asked to have it installed. Then somebody presumably would have come with a sales pitch, explaining it to me. But the fact that it was there and nobody told me about it is not good.' (ID312, STHW)

> ‘I think there’s a gap in my understanding, I think something they could have done better to explain is exactly how much more efficient it is and why.’ (ID608, CHP)

> ‘If the design engineer came round and told me, like lectured me one hour, on how they did it, I would quite enjoy it. As an engineer, I am fond of understanding… I can use the system more efficiently if I understand how it works. (ID640, CHP)

> ‘It would have been nice if when we first moved in if someone had explained that it was there, not necessarily from the agent, but the landlord could have got in touch, saying this is what you have, it’s good for heating efficiently.’ (ID817, ASHP)

> ‘There’s a lot of information to read through, I really don’t have the time. I would much rather have somebody, you know, I think sit down with me … and not a 5-10 minute dash around the house … Just a bit longer. I think you probably need a couple of hours really to go through how all the different things work in this house. (ID1154, MVHR & PV)

> ‘Developers are rewarded for installing such devices, but they should also be required to provide sufficient training/documentation on their use.’ (ID732, STHW – *comment made on questionnaire*)

Echoing some of these sentiments, the NHBC Foundation (2011b) has suggested that householders need more time at the hand-over stage in order to understand attributes of their low energy homes. They state that for ‘new homes, practical demonstrations and inductions are often offered’ (NHBC Foundation, 2011b, p. 9). From my research, however, I would conclude that although 15 of the 26 interviewees did receive some form of introductory home tour, this was often deemed inadequate and would not have promoted the effective enrolment of householders into using and maintaining their technology in a way that would maximise its potential to reduce domestic CO_2 emissions. This finding concurs with that from a recent UK survey of ten householders in MVHR-fitted new homes[101], where only 29% ‘found their home induction useful’ (NHBC Foundation, 2013a, p. 12); similarly, Stevenson et al. (2013) researched two new UK developments and established that handover processes typically excluded demonstrations of installed LZC technology.

New occupants are typically presented with a wealth of information to assimilate on how different aspects of their home function (such as kitchen and washing appliances). A few householders suggested that this was not the optimum time to instruct them on matters relating to LZC technology. Some felt it would have been more productive to have imparted such information once they had settled in and could focus better on what was being said. This viewpoint supports the notion of ‘reminder sessions’ for householders, a suggestion

[101] Built to CSH Level 6.

emanating from research on particularly low energy UK housing with a multitude of novel technologies installed (NHBC Foundation, 2011b, p. 9).

Confusion can arise when there are two or more groups providing conflicting information. In one development with three separate communal energy systems, the developer, management company, technology specialists and local planning department presented varying interpretations to householders on the intended role and current operating status of the different energy systems:

> 'Part of the issue is that the information that we have been provided with from when we first ever came to look at the development through to purchasing, then following our complaints *[to the developer, local authority and management company],* there seems to be a lot of misinformation, and a lot of contradictory information.' (ID786, communal biomass & CHP)

Verbal advice and instructions from developers may be instrumental in determining what householders come to expect from their technology in terms of energy provision, but this may or may not shape how householders subsequently interact with their technology. The following two examples illustrate this point:

> 'when we moved in we were told that *[the STHW system]* should provide 70% in the summer and in the winter maybe 20-30%.' (ID928, STHW)

Despite being informed that their STHW system should be able to provide the majority of hot water needs in summer-time, this couple had not thought to try and rely on it during this season. They still had the boiler come on two hours in the morning and evening to heat the water; nobody had advised them to do otherwise. In the next example, the householder's expectations had been curbed:

> 'But because *[the developer]* said it had something to do with 10% of your water will be heated – that's what they said that it would give you, 10% or so.' (ID295, STHW)

Believing that the technology would, at best, only provide 10% of hot water needs meant that this householder had never considered relying solely on the technology at any point. The conversation with the developer had set expectations so low that he had given the technology little attention during his four years in the flat. During the interview, this householder was surprised to learn that the technology had the potential to contribute more significantly to meeting hot water requirements. By this time, he had rented out his property and was disappointed at what he now regarded as a wasted opportunity.

A few interviewees mentioned that those who advised them on their technology did not seem to sufficiently understand it themselves:

> 'I don't think he really understands them.' (ID94, STHW) – *[commenting on the estate manager at an extra-care establishment and his knowledge of STHW technology]*

> 'And the developer didn't really seem to know what was going on with the heating anyway. … He didn't seem like he had read the manuals. It seemed like he'd been given a set of instructions for showing us around …' (ID833, STHW)

> 'Everyone said they're all new to it. So the people who were selling it to us couldn't explain it because they didn't understand it.' (ID804, CHP, communal biomass & MVHR)

One interviewee was a developer and had selected an ASHP for his new home and for the neighbouring two properties. He acknowledged that he did not know enough about the ASHP to adequately explain how it worked to potential buyers:

> 'Most people … coming round to look at it were positive but they didn't understand it and, sadly, I didn't understand it either: 'How does it work?' 'Don't know.'' (ID1023, ASHP)

This potential lack of understanding would constrain developers' ability to adequately inform and enrol householders into productive technology-user associations. Evidence for developers' lack of understanding of installed LZC technology comes from recent research on on-site sales teams (NHBC Foundation, 2013b), social housing (Monahan, 2013) and the handover process (Stevenson, Carmona-Andreu, & Hancock, 2013).

Stevenson & Rijal (2010, p.552) note how the 'formal introduction to the home is the first critical interface between the inhabitant and their interaction with the building' and that this introductory process can significantly shape 'the effectiveness of user interaction subsequently'. They highlight that evaluating these introductory processes is especially useful where developers have installed new types of technology. The findings from this research provide evidence of the shaping potential of such introductory processes; they also highlight that these processes tend to promote a non-interactive form of engagement with LZC technology, which may adversely influence the degree to which technologies are optimised, both in terms of their operation and maintenance (Section 8.3).

A large proportion of householders wanted more information and advice than received, not just on how the technology worked but on how to operate it, potentially alongside conventional energy systems, to maximise the benefits gained (a finding in line with research by Munzinger, et al. (2006) and Monahan (2013)). The additional sources of information to which householders turn are described in Section 7.2. In addition to insufficient advice, there are other factors that householders perceive as hindering their ability to optimise LZC technology, and these are discussed at various points in Chapters 7 to 10.

6.5 What kind of knowledge do departing residents impart to newcomers?

The research findings in this following section contribute to an under-researched area of study by providing a limited insight into the degree to which information on LZC technology passes between successive occupants of newly built homes. Where interviewees were not the first occupant of their home, I explored the nature of any information on the LZC technology imparted or made available by the previous occupant. I identified two relevant cases, both relating to owner-occupiers. In the first case, a couple moved in and found an instruction manual relating to the STHW system, but no verbal advice had been provided by the previous owner. Similarly in the second case, the new occupant was provided with documentation but no verbal advice:

> 'Well, when I moved into the flat, I was disappointed I didn't meet the owner ... So I asked the estate agent to ensure he was going to leave all the instructions. Well, the file is about four or five inches wide with all the instructions on what is in the flat.' (ID265, STHW)

Another interviewee had recently vacated his flat and was now renting it out via an estate agency. When asked whether his tenants knew they had a STHW system, he replied:

> 'They may not. They probably wonder what that white box in the cupboard is. We've got the instruction manual; we've left it there for them. They can see it's related to solar panels, but they may not know how it works.' (ID295, STHW)

This particular householder had lived with a STHW system for four years but was unclear as to whether it provided hot water or electricity, and the technology had not influenced his domestic activities in any way. Thus, in this instance, the absence of a verbal handover had its merits as any discussion might have misled rather than informed the new tenant. So, in none of the three cases outlined did the new occupants benefit from any technology-related knowledge gained by the previous occupants, though relevant documentation was transferred.

An instance where no documentation had been handed over, however, was noted during fieldwork, via a door-step conversation with someone who had not received any information at all from the previous, renting tenants. She was aware of equipment in her loft; she did not know what it was but said it was switched off. Based on my conversations with nearby residents, it seems probable that this idle equipment was part of a MVHR system. The observation that instructions on LZC technology are not always passed between successive occupants concurs with reports that this is typical of the passing on of household instruction manuals in general (NHBC Foundation, 2011b).

In none of the four cases noted had occupants received any verbal advice relating to the technology from the previous occupant, and will therefore not have benefited from any experiential knowledge that they might have gained. The findings in this sub-section suggest that departing residents do not form part of the informal distributed inscription (Section 3.4) pertaining to LZC technology. Instead, they may diminish the formal distributed inscription by not circulating relevant documentation. In such instances, previous occupants may hinder the development of subsequent LZC technology-householder associations rather than promote the re-domestication (Lie & Sørensen, 1996) process, and those commencing the re-domestication process may start out from a less-informed set of socio-technical associations.

6.6 Conclusions

The purpose of this chapter was to describe and appraise aspects of the embryonic LZC technology-householder association. In Section 6.2, I provided an improved understanding of LZC technology's agency within mainstream UK housing, with 39% of survey respondents acknowledging that the technology had positively contributed to the home selection process; in other words, 39% of respondents could be viewed as actively appropriating the LZC technology. For a proportion of the 37% who were ambivalent about such agency, the potential for this to manifest itself was prevented by either the absence of information on the technology within the marketing and sales process or the lack of attendance to any such information made available.

In Section 6.3, I contributed to a more informed evaluation of the adequacy of developers' documentation on installed LZC technology, as perceived by householders. The distribution of perceptions paints a polarised picture with 42% of those surveyed reporting satisfaction with the information, 46% reporting dissatisfaction and 12% adopting a middle ground. This polarisation extends across technology and tenancy types. Some of those initially reporting satisfaction with the information in the survey, provided a less favourable account when interviewed, describing the information as sparsely written or complicated. Others who reported satisfaction had not actually referred to the documentation – here, satisfaction appears based on the knowledge that they have it stored somewhere, rather than on its readability or usefulness, and any interactions with the technology have not been actively shaped by the documentation. For those expressing dissatisfaction with the information, the interviews highlight that this does not just stem from instances where there is insufficient documentation; it also arises where the information is incomprehensible or deemed to be misrepresentative of actual arrangements.

In Section 6.4, the research findings contributed to an improved understanding of the ways in which verbal advice received from housing industry representatives influences the development of LZC technology-householder associations, an area of study that has received little attention. 42% of interviewees did not receive any verbal instructions or descriptions relating to their technology when moving in, and many wish that they had. Where interviewees received some form of home tour which referred to the technology, the housing industry representative typically assigned the householder a passive role with regards to the technology, advocating that they did not touch it or change the settings; in effect, these representatives verbally black-boxed the technology and configured the householders as passive users with a non-existent or minimal operational role. A significant proportion of householders were initially shaped by verbal instructions received, but a few were sufficiently knowledgeable and confident to deviate early on from the non-interactive role advocated. Several householders thought that developers themselves lacked a sufficient understanding of the technology and that this was the underlying cause of the inadequate level of advice given.

In Section 6.5, the research findings contributed to another under-researched area of study by providing a limited insight into the degree to which information on LZC technology passes between successive occupants of newly built homes. In three cases, documentation had been left for new occupants but in one case it had not. In none of the four cases had occupants received any verbal advice relating to the technology from the previous occupant, and will therefore not have benefited from any experiential knowledge that they might have gained. These findings suggest that departing residents do not form part of the informal distributed inscription pertaining to LZC technology (Section 3.4). Instead, they may diminish the formal distributed inscription by not circulating relevant documentation. In such instances, previous occupants may hinder the development of subsequent LZC technology-householder associations rather than promote the re-domestication (Lie & Sørensen, 1996) process, and those commencing the re-domestication process may start out from a less-informed set of socio-technical relations.

Chapter 7: Getting on with LZC technology

7.1 Introduction

Having explored aspects that contribute to the shaping of embryonic LZC technology-householder associations, in this chapter I describe and appraise how householders come to use, regard and interact with their technology in the longer-term, identifying key determinants influencing the progressive shaping of LZC technology-householder associations. Four elements to this are discussed, encompassed mainly by the objectification and incorporation components of domestication (as discussed in Section 4.2)[102]. Firstly, I consider the extent to which householders seek to understand their technology by referring to, and supplementing, the information initially received. The findings demonstrate the distributed nature of the formal and informal information sources guiding householders' actions (Section 7.2).

In Section 7.3, I examine the ways in which LZC technology and associated controls are arranged within the home and how these arrangements influence householders' interactions. I also attend to the influence of the initial technological settings. I then focus on how feedback from the technology engages householders and shapes perceptions and actions, revealing the different modes of feedback associated with four technology types (Section 7.4). Lastly, I highlight how certain events may significantly influence the development of LZC technology-householder associations (Section 7.5).

Through the discussion, the following five research questions are addressed: *which sources of information do householders refer to in order to improve their understanding of LZC technology (Section 7.2); how are users configured by the design, placement and settings of LZC technology (Section 7.3); to what extent does feedback from LZC technology engage householders and shape actions (Section 7.4); to what degree does LZC technology exhibit agency in everyday temporal affairs (Section 7.4); and, what trials (experiences, interactions or receipt of new knowledge) trigger householders to shift and re-stabilise their socio-technical relations as part of the on-going domestication process (Section 7.5)?*

[102] Repair and maintenance processes, intra-household associations and ascribed meanings are also encompassed by these two domestication components and are attended to in Chapters 8 and 9.

7.2 Seeking to understand LZC technology

In this section, I establish the extent to which householders refer to, and seek to supplement, the information initially received, given that 46% of surveyed householders were dissatisfied with such information (Section 6.3). 61% and 35% of surveyed householders (n=122) refer to the instruction manual and some form of home user guide respectively (Figure 7.1), information likely to have been initially provided and therefore part of the formal distributed inscription for the technology. This finding contrasts somewhat with previous research that suggested (in qualitative terms only) that householders 'do not tend to look at manuals' (NHBC Foundation, 2012c, p. 12). The main alternative information sources, to which 44% of householders in this research turn, are the technology's installer or a maintenance company; the reason for this is examined in Section 8.2. The next most popular information source, to which 29% of householders turn, are neighbours (or potentially other acquaintances) who have similar technologies. The extent and nature of these inter-household associations is examined in Section 9.3. 18% of householders make use of the manufacturer's helpline and the same proportion use the internet to search for information. Lastly, 14% identified a household member as an information source; the extent and nature of intra-household discussions on LZC technology is explored in Section 9.2.

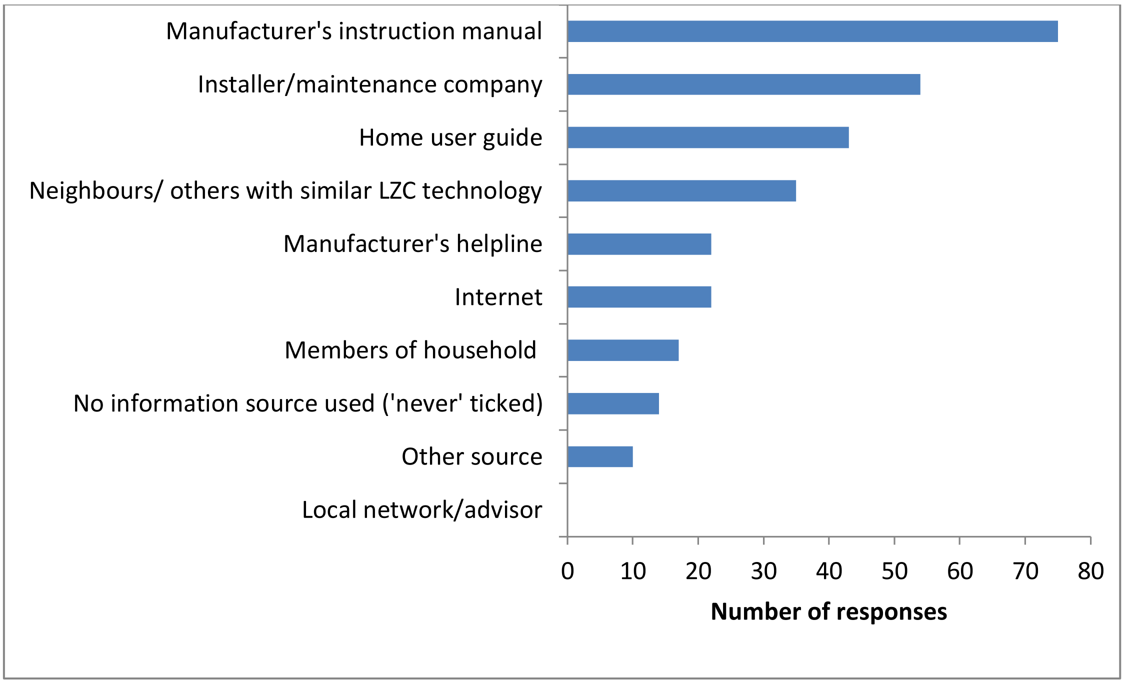

Figure 7.1. Which sources of information do householders use to help them maximise the performance of, and benefits from, their LZC technology? (n=122)

These results illustrate the diversity of supplementary information sources turned to as householders build-up their socio-technical networks in pursuit of a better understanding of their newly acquired technology (also evident from Munzinger et al.'s (2006) study on retrofitted and new build PV systems). These supplementary sources form part of the informal distributed inscription that shapes householders' interactions.

11% of surveyed householders, however, had never referred to any information on their technology. This group consisted of 14 householders, of which three were served by communal LZC technology, where responsibilities for operation and maintenance would reside with a management or energy services company. The remaining 11, however, would have had full or partial (in the case of shared-ownership arrangements) responsibility for their technology. Given the lack of reference to any information source, it would be tempting to deduce that these householders were all indifferent to their technology. However, through the survey, only five confirmed such disinterest, two were ambivalent about the technology and the remaining seven expressed interest in it.

To summarise, the findings demonstrate the distributed nature of the formal and informal information sources guiding householders' interactions with their LZC technology. I now turn to the more physical aspects of these installations.

7.3 How are householders configured by design & settings?

7.3.1 Introduction

In this section, I consider the ways in which LZC technology and associated controls are arranged within the home and how these arrangements shape (or configure) the nature of householders' interactions. I also consider the extent to which initial technological settings influence householders. (Monitors and meters, and the feedback they provide, are considered separately in Section 7.4). The analysis is based on 26 interviews and also door-step conversations. Three technology types (STHW, ASHP and MVHR systems) are examined to illustrate the various ways in which users are shaped by designs and settings. I turn first to STHW systems, the most predominant form of technology installed (Section 5.6).

7.3.2 STHW

The main components of STHW systems mentioned by householders were roof-top panels, hot water tanks, pumps and monitors. Particularly in blocks of flats, panels are often situated out of view, limiting visual reminders of their presence. The hot water tank, pump and associated pipework are similarly placed out of general view in a cupboard; here, if component parts are displayed, their seeming complexity can instil confusion, deterring householder interactions:

> '… there is a huge amount of pipework in there. There's the hot water tank, … there's all the heating pipes, there's about three pumps in there along with a couple of meters. I mean, it's just chaos.' (ID928, STHW)

> '… this doesn't look very neat, there seems to be lots of pipes and tubes and things.' (ID256, STHW)

Householders can be further hindered from taking an active interest by the technology's partial placement in an airing cupboard, where it may sit hidden behind shelves of linen. This is, of course, a typical location for conventional hot water tanks and this constancy reinforces a business-as-usual approach from some householders, who pay no more attention to their STHW system than they would a conventional hot water system:

> 'Because it was hidden away in the cupboard, if you didn't go in the cupboard, you forgot it was ever there.' (ID295, STHW)

Typically, airing cupboards are positioned in accessible hallways, but one interviewee mentioned it was inconveniently located in someone's bedroom:

> '…it's in my flatmate's room, so it's not something I check.' (ID833, STHW)

These examples illustrate how the ways in which the technology is embedded within the spaces of the home can contribute to configuring householders as passive users (which concurs with Ghanem's (2008) analysis of domestic PV systems).

Householders moving in with STHW systems can be partitioned into those that feel sufficiently confident to override initial settings for the hot water system and those that do not. The former will be considered first. Conventional hot water systems typically consist of an immersion heater and/or gas boiler. In one flat, although the immersion was initially set to come on nightly for a defined period, a pre-installed programmer enabled the householder to amend the settings and reduce immersion winter usage to one hour. This timing was halved in spring and autumn, with immersion usage ceasing in summer. In certain other flats, immersion control was initially enabled only via an on/off switch; here, absence of a programmer limited the householders' ability to tailor immersion usage without significant input of effort. One householder willing to put in this effort, manually switched the immersion on and off between 10.30pm and 11.30pm on days when the STHW system could not meet her needs. Here, the immersion had been set-up by the installer to kick-in when the off-peak electricity supply commenced at 10.30pm, but without her input it would have continued running until 7.30am, which she considered unnecessary. Another interviewee without a programmer kept his immersion on constantly in winter, but switched it off in summer once the STHW system could adequately meet his hot water requirements. These examples illustrate the range of ways in which householders override initial settings, as constrained and enabled by the affordances (Marres, 2010)that available controls provide.

For those retaining initial settings, one explanation given was that STHW and conventional systems appeared unapproachable. Poor understanding of how systems worked, together with seemingly complex programmers, led certain householders to adopt unquestionably the settings in place. For one such interviewee, whose immersion lacked a programmable unit, the immersion was switched on constantly all year:

> 'The immersion heater is on all the time and it just keeps it topped up, so if there is kind of no hot water coming from the solar thermal, it will run the entire heating system. I think it's controlled by an electronic system which just kind of measures the amount of hot water coming from the solar thermal and then goes, right we need this extra amount coming from the immersion …' (ID833, STHW)

She had not questioned the soundness of this set-up as the developer had advised her to leave it this way and she assumed the settings optimised the technology. Another householder had not altered any initial settings (including that for the gas boiler) as he did not understand the technology. These examples highlight that there are householders insufficiently confident (or inquiring) to alter initial settings, partly due to the unapproachability of household energy systems[103]. This finding emphasises the importance of installers (or potentially developers) selecting appropriate settings.

With regards to appropriate settings, research has shown that the effectiveness of STHW systems is dependent on whether and when alternative modes of water heating are employed (Hill, et al., 2011; Lloyd & Kerr, 2008; Hernandez & Kenny, 2012). Hill et al. (2011) found that 65% of 55 STHW-users had their boiler on in the morning and that this caused them to lose 75% of their potential energy savings. They concluded that STHW-users should avoid using

[103] The perceived complexity of household energy systems incorporating STHW systems has been observed elsewhere (Bell, et al., 2010).

alternative modes of heating systems until the 'main warmth of the day' has passed (Hill, et al., 2011, p. 1). The research in this study has highlighted that such guidance has not been effectively circulated to many householders, as discussed further in Section 7.4.2.

In summary, the research highlights that the low visibility, inaccessibility and perceived complexity of STHW systems may hinder householders' interactions with this technology. Accordingly, householders can be partitioned into those that override initial settings for the combined hot water system, in order to reduce overall energy consumption, and those that do not. Reluctance to interact physically with the technology was also noted with ASHPs, as turned to next.

7.3.3 ASHP

Three interviewees had an ASHP, providing space heating and hot water. Regarding the extent to which householders had been shaped by the technology's design and capabilities, two common themes emerged; space heating patterns and modes of temperature control. All three had been advised, via written or verbal instructions, to run the ASHP constantly during periods of the year when heating was required, and they followed this advice. (Here, the actions subscribed to by the householders met the requirements of the technology's prescription (Section 3.4)). The systems incorporated comprehensive programmers that enabled a degree of fine tuning to be introduced into heating patterns. However, each householder avoided the programmer and relied instead on the thermostat as the primary control mechanism (a finding also reported for conventional heating systems (NHBC Foundation, 2012c)). This reliance on the thermostat has been observed in a larger-scale study of GSHP and ASHP users, where only 54% of heat pump[104] users considered controls and displays to be 'easy to understand and use' (Caird, Roy, & Potter, 2012, p. 289).

One householder from this research, for example, ran the heating constantly at 20°C during the day and 18°C during the night:

> 'And we found with the pump that we have now we simply set the temperature with the thermostat and then all around the house we work it at that temperature … after 8pm at night, which is when the kids go to bed and everyone is snugged in, I set the thermostat and the boiler will follow whatever the thermostat *[states].'* (ID817, ASHP)

[104] Covering ASHPs and GSHPs

The other two households also ran the heating constantly, with the thermostat at 21^{o}C '24/7' in one case and, in the other, night-time temperatures were set at 15^{o}C, rising to 18^{o}C during the day. In summer-time, this last householder kept the ASHP system on as this constituted the easiest available course of action:

> 'I just leave it set between 15^{o}C and 18^{o}C. And, alright, if temperatures drop then it'll come on and if not, it won't. From that point of view, I haven't got to think about it.' (ID1056, ASHP)

Adopting this approach removed any need to interact with the programmer and this may have been a factor in not switching the system off in summer-time; this householder found the 'tiny, weeny knobs' on the programmer hard to discern. For the other two householders, the perceived complexity of the programmer may have led to their reliance on the thermostat:

> '… it's got everything in there; it's got a seven day programmer and you have an 'on' and 'off' four times a day. So you can programme it to what you want it to do ... I think basically it's fairly straightforward, if anything, it's almost over-complicated and doesn't need to be there – but that is modern technology.' (ID1023, ASHP)

This householder regarded the presence of the detailed programmer as surplus to his requirements.

As with conventional central heating systems, ASHPs provide space heating by distributing heated water (via under-floor pipework or radiators). A key difference, however, is that the water temperature achieved by an ASHP is significantly lower than that from a boiler (DEE, 2011). In order to attain customary indoor temperatures, therefore, ASHPs need to compensate for this limitation by operating for longer periods of time in order to deliver the quantities of heat required. Likewise, ASHPs are not able to heat cold spaces up as quickly as conventional heating systems[105] due to their lower heat output, a relative limitation that again supports a more constant mode of operation to prevent significant drops in indoor temperatures.

Given the fundamental design, workings and attendant limiting capabilities of ASHPs, householders have had to use it in particular ways in order to attain customary indoor temperatures (also noted by Owen, Mitchell, & Unsworth (2013)); this has been learnt through 'trials' (Lehtonen, 2003, p. 364) and instances of discomfort. To secure desired day-time levels of thermal comfort, resultant night-time temperatures have become higher than before. One

[105] In research by Caird, Roy & Potter (2012, p.291), for example, 26% of 27 ASHP-users complained 'about the slow warm up of the heating'.

householder, for example, had night-time temperature now at 15°C, compared to 9°C in her previous home. The other two householders previously turned heating off at night-time. Thus, an unsought, but not unwelcome, by-product of altered heating patterns is additional nocturnal thermal comfort (also reported by Singh, Muetze, & Eames (2010))[106]. This is not deemed to be an example of 'comfort taking'[107] (Owen, Mitchell, & Unsworth, 2013, p. 830) but more the *imposition* of nocturnal comfort in order to attain habitual day-time comfort levels. In this research, ASHPs have exhibited agency through their ability to cause householders to change their heating routines. Householders have developed effective associations with the technology that deliver required daytime comfort levels, but in so doing required night-time comfort levels are exceeded. I now turn to the last technology considered in this section, MVHR systems, which have impacted on householders in rather different ways.

7.3.4 MVHR[108]

The findings discussed in this section are derived from five interviews and four door-step conversations. A major design aspect influencing how users reacted to MVHR systems centred on the tolerability of associated noise. In certain instances, the noise was deemed intolerable and householders decided to either reject the technology by disconnecting it or partially reject it by reconfiguring it; here, the technology's noisy nature caused it to fail its initial 'trial' (Lehtonen, 2003, p. 364)(Section 3.4), causing users to react and re-shape the technology. This illustrates the unintended agency (Section 3.4) that technologies may exhibit, which in this instance would be construed as negative in relation to CO_2 reduction efforts. These cases are examined further in Section 7.4. This section focuses instead on those who *do* use the technology and how they are influenced by its layout, design and controls.

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[106] Caird, Roy, & Potter (2012) also report that 65% of 23 ASHP-users often or usually have space heating on at night-time, but it was unreported as to whether this always constituted a change in previous routines.

[107] Where cheaper heat provision leads householders to afford more energy in the pursuit of desired comfort levels (Owen, Mitchell, & Unsworth, 2013).

[108] MVHR systems contribute to space heating by recycling heat; heat is extracted from stale air to be discharged via the ventilation system and then inputted into fresh air entering the building. In new homes, MVHR systems are expected to operate constantly to reduce energy consumption and to provide sufficient ventilation. There are typically two operating modes: winter mode, when heat is recycled, and summer mode, when heat is not recovered but mechanical ventilation continues.

In households where the technology had not been actively rejected, the MVHR units were either installed within the attic or within cupboards on the top floor, in relatively unfrequented spaces. The controls tended to be limited; apart from an on/off switch, which householders were typically unaware of, the controls amounted to a switch enabling householders to alter the technology's setting between summer and winter operating modes. The frequency of this adjustment differed between two particular households; one where the switch was in a well-used location and one where it was isolated. With the former, the switch was accessibly located on the ground floor and the householder interacted with it in response to outside temperatures and perceived levels of stuffiness inside:

> 'You can do that whenever you want to, can switch it to summer mode. Just when it gets – I just do it when it gets – you can do it manually on the thing, and then switch it back to winter the next day if it gets cold again.' (ID1154, MVHR & PV)

So, in this instance, the switch-over between operating modes was a flexible, interactive arrangement wherein the householder was effectively enrolled in this aspect of the technology's control. In the second household, the switch was on the third floor and the householder needed to remember to switch it over in spring and autumn:

> '… the red/blue dial is actually in a cupboard, in the bathroom on the top floor. It's about as tucked away as it could be really.' (ID424, MVHR & STHW)

This was the only technology-user interaction; the positioning of the technology and switch in unfrequented places configured the householder as very much a passive technology-user with a limited bi-annual role:

> '… the ventilation system feels like essentially a passive thing from my point of view, I just twist a knob … You could argue that as you only have to do it twice a year that's not a big hardship going up there, but I suppose people forget about it completely; whereas, maybe if you had it alongside the central heating control panel, they'd see it on a more general basis.' (ID424, MVHR & STHW)

Although this householder remembered to fulfil his limited role, he suggested that not everyone would[109]. A need for such user-interaction is circumvented where the design excludes the need for householder involvement in making this switch (here, more competencies are ascribed to the technology (Section 3.4)). Such a situation was described by one householder whose MVHR system had always been on an 'Auto' setting and 'so runs itself'. His understanding was that the system changed its settings automatically, depending on

[109] In Macintosh & Steemers' (2005) study on 38 MVHR-users in the UK, 47% did not interact with operating controls, but this was mainly attributed to a lack of understanding of what the technology was for.

outside temperature, for example. This householder was excluded from any direct, interactive role by the technology's location and control settings (wherein it had assumed a black-box status); however, he did take on board an indirect, interactive role whereby he generally kept windows shut as he understood that this optimised the system. This householder considered that maximising the MVHR system's effectiveness had contributed to a low dependence on the gas central heating system, which was only required for a couple of months a year.

For these householders, the technology had been switched on by someone prior to them moving in, and the on/off switch's location was unknown. This can be considered a 'hands-off' design where users are not enabled to fully control the technology. This design approach is, however, not failsafe; it may not deliver the intended outcome of a continuously operating system when someone moves into a home where the technology has either not been activated by the developer or has been deactivated by the previous occupant. Examples of such scenarios were provided through door-step conversations. One householder described how there was a large tube-like structure in the loft, which was switched off. She had moved in to her property after it had been vacated by previous tenants and no information had been transferred. From talking to some of her neighbours who knew they had a MVHR system, it is likely that this householder also had such a technology installed. One of these neighbours described how she had a MVHR unit in the attic but she had never seen it. There was no indicator or switch in the living space to show whether it was actually switched on and there was no sound emanating from it.

These cases demonstrate how distancing users, and configuring them as passive, can backfire. Although this design approach may successfully prevent householders from tampering with the technology and accidentally deactivating it, this distancing can also prevent the technology from being activated by those moving in, should this be necessary; the technology's out-of-sight location and the lack of evident, labelled controls can lead to systems remaining dormant long-term.

It is also evident that separating the technology from householders does not effectively protect it from their actions when it is unacceptably noisy (Section 7.4). In one such example, a householder wanted to switch their MVHR system off for the majority of the time but could not locate its on/off switch. After initially protesting that the unit needed to stay on, the development site manager relented and identified the on/off switch for her in the airing cupboard. It was:

‘Unmarked, just like a little fuse switch.’ (ID805, CHP, communal biomass & MVHR)

This resident was not the only one in her development who was driven to reconfigure the technology by its unacceptable noise levels. This illustrates that it would be difficult to design out the potential for householders to reconfigure this technology if they really wished to[110].

In this section, I have considered how the physical arrangement of LZC technology and associated operating controls, and the technology’s inherent capabilities (for ASHPs), can shape the extent and nature of householders’ interactions with it. Attending to three technology types has illustrated the different ways in which these interactions are influenced by design and settings. According to Stevenson & Rijal (2010, p.552), there ‘has been little evaluation of the various user interfaces in the domestic sector and their effect on housing performance’. This section’s findings and those in Section 7.4 (as both summarised in Section 7.6) contribute to an improved understanding of how the design of LZC technology and how it is embedded within the home influences its usage and associated performances.

7.4 To what extent does feedback engage householders & shape actions?

7.4.1 Introduction

In Section 7.4, I shift the focus onto householders’ engagement with feedback on how their LZC technology is operating, both in terms of what feedback householders engage with and whether this influences actions. Published research on feedback from domestic energy systems has mainly focused on the behavioural impact that total household energy consumption data has on householders (Darby, 2010; Hargreaves, Nye, & Burgess, 2010) but engagement with LZC technology-derived feedback in mainstream new housing has not yet been researched in any detail. In addressing this omission, I consider the feedback content and the positioning of any feedback devices[111] (monitors and meters). Four technology types (STHW, ASHP, PV and MVHR systems) are examined in order to highlight the various ways in which users become shaped by formal and informal modes of feedback.

[110] In a review of research into domestic energy systems, the NHBC Foundation (2012c) concluded that removing control of these systems from householders can lead to frustration.

[111] For STHW and PV systems, such devices pertain to energy generation as opposed to energy consumption (as researched by Darby (2008) and Hargreaves, Nye, & Burgess (2010), for example); for ASHPs, feedback devices are restricted to the normal household energy consumption meters.

7.4.2 STHW

15 interviewees had STHW systems which included, in all but one case, feedback monitors. Based on frequency of interactions with available feedback and the degree to which actions were subsequently shaped, five householder categories were distinguished (Table 7.1). At the most interactive level (Category I), one householder sought feedback (via the monitor and informal means) every few days year-round, and this influenced actions on an on-going basis:

> 'You can tell to a certain extent because it's a very big tank and it's in a cupboard … so whenever I walk in the cupboard, you can always feel the heat … And walking in the cupboard today *[27th February]*, it does feel reasonably warm in there so I certainly won't bother to put *[the immersion]* on tonight.' (ID94, STHW)

This householder regularly dried her bath towel in the airing cupboard containing the hot water tank. She only used her immersion, if required, between 10.30pm and 11.30pm, thus any heat emanating from the tank during the day derived from the STHW system. As the immersion switch was in the cupboard, and she switched the immersion on manually, she effectively made a daily conscious decision about whether to just depend on the STHW system, as guided by the informal thermal feedback received and also monitor readings:

> '… there's a temperature gauge as to the temperature of the water coming back down, or whatever it is. Yesterday, was it yesterday when the sun was shining? Yes, it had got up to 60 degrees, which was pretty good for this time of the year *[27th February].'* (ID94, STHW)

Thinking through this case, a combination of routines (drying towels in the airing cupboard, manually activating the immersion, if needed, and referring to the monitor), coupled with a sensitivity to the hot water tank's thermal feedback, enabled this householder to respond flexibly and knowledgeably to the technology year-round. She thereby maximised its contribution to hot water provision (the solar fraction[112]). However, the timing of her hot water consumption remained unaltered - all the major hot water draws occurred late evening, as was her norm in previous homes. This singular case represents an example of year-round, influential interactions with the feedback device and an informal mode of feedback, which shape behaviour on an on-going basis (in terms of the potential for daily adjustments in immersion usage). Here, the STHW system's on-going agency is enabled by, and distributed

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[112] The solar fraction can be defined as follows (rewording the equation provided by BRE (2008)):

Solar fraction = (Heat from STHW system)/(Heat from STHW system + Heat from boiler or immersion)

A range of measured and estimated solar fractions have been quoted for STHW systems: 40-50% (EST, 2006a); 35% (EST, 2010a); 9-98% (with a median of 39%) (EST, 2011b) and 26-70% (BRE, 2008).

through, the formal and informal modes of feedback with which the householder chooses to engage.

In Category II, frequent feedback was sought by householders but this only influenced the timing of specific seasonal actions. The first example involves a householder who checked his monitor on alternate winter days and every summer day:

> '… when I know it's working I check when I come in what the temperature of the water is and you might check in the morning as well, so you have got some idea of whether it's heated up or not.' (ID155, STHW)

This householder had a more structured dependence on his immersion than the previous example in Category I, whereby it operated for an hour on winter days, 30 minutes on spring and autumn days and not at all in summer-time. So, although he had highly frequent interactions with the monitor, the feedback obtained was only acted upon infrequently when gauging when to switch between seasonal heating patterns, as opposed to shaping daily immersion usage. In summer-time, solar-heated water met all his needs and he never altered the timing of hot water consumption to fit in with outputs from the STHW system. This mode of interaction with feedback was observed with another householder, where the interaction was weekly:

> 'There is a multi-function dial on the pump unit, where the solar thermal water comes in to the tank cupboard. And the thing I look at almost exclusively is what temperature the collecting water is, because that gives you a fair idea about how things are working.' (ID240, PV & STHW)

This householder had the boiler on three hours morning and evening in winter, three hours per morning in spring and was expecting to switch it off in their first summer in the home. These two examples can be viewed as year-round, inquisitive interactions with feedback devices which lead to the shaping of behaviour on a seasonal basis (confined to the timing of seasonal adjustments in immersion usage).

Category III householders also sought feedback frequently but alternated between two (not three) heating modes, where conventional heating systems were either on or off – and there were no other seasonal adjustments. One householder checked her monitor every few days, whilst using the airing cupboard, to see what temperature the panel was heating the water to:

> 'Well, I have a very big airing cupboard. The towel that I use to shower – I dry it in there. If I want to, I can look and see what the temperature is.' (ID265, STHW)

The monitor also showed a yellow light when the technology was operating. This householder moved in in August and depended solely on her STHW system until October, after when the boiler was operated 30 minutes morning and evening. This heating pattern sufficed the whole winter. The interview took place mid-March when she was beginning to think the STHW system's effectiveness was approaching a point when she could switch the boiler off. The second householder in this third category checked the monitor on a weekly basis:

> 'So, it is exceedingly efficient but it is really only worth collecting the heat from it, say, April through to October.' (ID273, STHW)

Here, monitor checking continued throughout summer, partly because the system had failed previously and so the householder remained watchful. These two examples involved year-round, inquisitive interactions with feedback devices which led to the shaping of behaviour on a twice-yearly basis (confined to selecting the twice-yearly occasions when the boiler was either switched on or off).

For the examples mentioned so far, the monitor has been accessible and intelligible, and the feedback of most interest has been the temperature of the liquid returning from the panels.

Category IV householders also alternated between two modes of hot water heating, where the conventional heating system was either on or off – but they are distinguished from Category III householders by a less frequent or minimal interaction with the feedback monitor. One householder in Category IV expected to rely on the STHW system from May to October. The monitor was consulted on an infrequent basis to check the temperature of the fluid returning from the panel; the various other monitor settings were not engaged with as they were not understood:

> '… that's the only thing that it will show unless I go in there and press various knobs – and then I get things that I'm not really sure about. So I don't want to fool around with it as if I get red lights instead of green ones, I'm not happy.' (ID312, STHW)

This householder was not really clear on what the green and red lights represented, but there was normally a green light showing which he took as confirmation that the system was set-up satisfactorily. Another householder in this category relied on the technology for a few months in the summer, and for the rest of the year the immersion was constantly on. He appeared to consult the monitor around the time when he expected the switchover to take place, but other than that checks were infrequent:

> 'Once I know it's working well, I don't bother to look at it.' (ID826, STHW)

For this householder, the monitor was not readily readable and took some effort to decipher:

> 'You've got to peer at it quite closely. It's at the back of the airing cupboard …' (ID826, STHW)

The remaining householder in Category IV was very enthused about her technology and its ability to meet her family's hot water needs from April/May onwards. The monitor, however, was located inconveniently on the third floor which limited how often it was consulted. They checked the monitor to assist with determining when to switch the gas boiler off:

> 'It's kind of a case of checking for about a week - is it still heating, is it okay, can we risk it yet? Can we turn it *[the boiler]* all off? … So … once daylight hours are long enough, then it seems to be working absolutely fine, from then until the hours get shorter. Once it *[the boiler]* is off, I don't have to think about it, it's fine.' (ID1030, STHW)

She would prefer to have had the monitor installed elsewhere:

> 'In the kitchen, or in a hallway downstairs; just somewhere where I can see it all the time would be really convenient.' (ID1030, STHW)

These three cases are examples of infrequent, influential interactions with feedback devices which lead to the shaping of behaviour on a twice-yearly basis (confined to selecting the twice-yearly occasions when the gas boiler is either switched on or off).

For 60% of the interviewees, assigned all to Categories I to IV, the STHW systems had exhibited agency through their ability to cause householders to introduce new feedback checking routines and altered dependencies on conventional water heating systems. However, the installations have not demonstrated an ability to temporally order the interviewees' hot water consuming activities as no incidents of load shifting were evident. There was some limited evidence of load shifting, however, from the wider population of surveyed householders. In response to a question relating to whether installed LZC technology had caused householders to do things differently, various householders had elaborated on their selected response (ranging from 'strongly agree' to 'strongly disagree') in the free text section provided. Here, three STHW-users revealed a degree of load shifting was taking place:

> 'I pay attention to when hot water will be available e.g. for showers.' (ID274, STHW)

> 'Changing times we shower to take advantage of the solar heating (afternoon/ evening).' (ID429, STHW)

> 'I might consider showering later in the day if it is sunny.' (ID682, STHW)

The extent of such load shifting for the remaining surveyed STHW-users is unknown, however.

The more in-depth findings obtained from the interviewees in this research contrasts with Caird & Roy's (2008) interviews with 39 STHW retrofitters, where 47% reported evidence of load shifting. This difference, however, may support the view that active installers of STHW systems are unrepresentative of the wider population in their degree of commitment to these technologies (Rohracher, 2003). In a study of five passive STHW households[113], for example, Dobbyn & Thomas (2005) reported evidence of only one undertaking any degree of load shifting.

In the last category (Category V), a lower level of interaction and shaping was presented by those who rarely, if ever, checked the monitor and who always kept the conventional hot water system on (though sometimes for different periods of time between summer and winter). These households, then, used their conventional system 'in competition' with the STHW system (BRE, 2008, p. 16). They rarely checked the monitor because it was either inaccessible or indecipherable and, in one case, absent. One householder estimated they looked at the monitor 'every quarter' – they 'never really got to grips with' what the monitor's display was telling them, and would have preferred a simple on/off message indicating whether the STHW system was contributing:

> '… every time you opened the cupboard, we kept the towels in there as well, you noticed a little box there and you sometimes had a little look at it, but other than that … it was weird, it had sort of a picture, looked like an engine… And then you would have like a flashing bit on the panel that meant it was working.' (ID295, STHW)

This householder would have preferred the monitor in a more frequented place, such as the kitchen:

> 'Because it was hidden away in the cupboard, if you didn't go in the cupboard, you forgot it was ever there.' (ID295, STHW)

Below are two further examples where the monitor was inaccessible:

> 'I haven't looked at it … It is so inaccessible … It's right at the back of the airing cupboard, and you have to pull all the shelves out to get in there … It's not helpful and of course you are not going to pull all the towels on the racks out … It's a very deep airing cupboard.' (ID256, STHW)

> 'If I ever moved it, it would be done in such a way that it's in a panel outside the airing cupboard.' (ID829, STHW)

[113] Either moving into homes pre-fitted with STHW or having STHW retrofitted by the landlord

In the last example, the monitor was hard to see due to low light levels. For one couple, the profusion of STHW-related equipment in the airing cupboard had deterred them from interacting at all with the monitor:

> 'It just looks too complicated.' (ID928, STHW)

In this instance, the equipment's general complexity had framed the monitor as something unapproachable. Instead, they had come to rely on an unintended form of auditory feedback (which contributed to the technology's informal distributed inscription):

> 'In fact, the only reason I know that it does work is in the afternoons, if you go upstairs, it's three floors, if you go up to the top you can actually hear almost like a hum, so you know that it's come on … It's part of the bathroom, so when you're in the bathroom, you can hear it in the roof.' (ID928, STHW)

In another household, the monitor in the airing cupboard was set high on a shelf, behind sheets:

> 'I'm a little bit too short to be able to read that easily and it's in my flatmate's room, so it's not something I check.' (ID833, STHW)

She would rather have had the monitor positioned more accessibly:

> 'Next to the actual space heating thermostat, as that's the one I check.' (ID833, STHW)

Additionally, she did not know how the monitor worked or what it showed, highlighting that poor understanding can also hinder householder-monitor interactions. For Category V householders (comprising six out of the 15 interviewees), the absence of interactions with feedback devices meant there were no opportunities to be shaped by such mechanised feedback. Here, householders were typically deterred from engaging with feedback by the inaccessibility, indecipherability or, in one case, absence of feedback devices. In these cases, the absence of householder engagement with feedback appears to curtail the ability of STHW systems to exhibit agency, as in each case the householder's dependence on conventional hot water systems remains continuous. For a number of Category V householders, ceasing this dependence had not been contemplated as they were unaware that this might affect the STHW system's performance and their ability to save on energy costs; in other words, the act of switching off conventional hot water systems in summer-time had not constituted common sense.

Category	Categorisation of STHW-users based on engagement with, and shaping by, feedback devices
I	*Year-round, influential* interactions with feedback devices which lead to the shaping of behaviour on an *on-going* basis (in terms of the potential for daily adjustments in immersion/gas boiler usage).
II	*Year-round, inquisitive* interactions with feedback devices which lead to the shaping of behaviour on a *seasonal* basis (confined to the timing of seasonal adjustments in immersion/gas boiler usage).
III	*Year-round, inquisitive* interactions with feedback devices which lead to the shaping of behaviour on a *twice-yearly* basis (confined to selecting the twice-yearly occasions when the immersion/gas boiler is either switched on or off).
IV	*Infrequent, influential* interactions with feedback devices which lead to the shaping of behaviour on a *twice-yearly* basis (confined to selecting the twice-yearly occasions when the immersion/gas boiler is either switched on or off).
V	*Absence* of interactions with feedback devices means that there are *no* opportunities to be shaped by any such mechanised feedback.

Table 7.1. Categorisation of interviewed STHW-users based on engagement with, and shaping by, feedback devices

Table 7.1 summarises the five categories of STHW-users as derived. Table 7.2 draws together the various feedback-related characteristics for each category – the results suggest that the monitor's accessibility and the feedback's intelligibility are factors which affect the frequency with which feedback is sought, which in turn influences the potential for householders to be shaped by such feedback. The findings suggest that if the basic aim is for householders to try and rely on STHW systems in summer-time, then the accessibility and intelligibility of feedback monitors is of relevance.

Category I to IV users relied on their STHW system (thus optimising the solar fraction) in summer-time and thereby experienced the efficacy of their system during this period. Only one of the five who interacted most frequently with their monitors (Categories I, II and III) felt the need for any further feedback to be made available. There was a common view amongst Category V users, however, that they would benefit from additional feedback. These householders had never switched off their conventional hot water system and had therefore never received any unequivocal demonstration of the STHW system's capabilities; additionally, the solar fractions attained would have been considerably less than they could have been (BRE, 2008; Hernandez & Kenny, 2012):

> '… there is no way of knowing whether it is working, whether you can change when it's working and whether you can change your habits to see if it's working or not….' (ID829, STHW)

> 'It *is* just a question of information. I don't know what's going on, what it's doing. In some ways, that is nice because I don't have to worry about it until it breaks, which it hasn't done yet. On the other hand, I don't have any idea of how much *[solar]* heated water I'm actually using.' (ID833, STHW)

> 'The trouble is, we've moved from a six-bedroom house down to a four-bedroom semi-detached and with prices going up and down all over the place, it's been really hard to tell if we've had any benefit from it.' (ID928, STHW)

This last point was echoed by several interviewees - because previous homes differed in terms of age, size and/or occupancy, energy efficiency and energy demand levels also differed. This removed the possibility of comparing bills between homes to get an idea of financial savings that might be accruing from the STHW system. This point also emerged from a previous study on five new homes (NHBC Foundation, 2012d).

Category V users suggested improvements that could be made to feedback (Appendix 19). A common view was that more informative feedback would be beneficial, such as knowing the proportion of hot water needs being met by STHW systems, when the system was working, and how much was being saved in monetary terms. This desire for more informative feedback[114] is seen to extend to active STHW installers in Caird & Roy's (2010) research, where only 47% were satisfied with available feedback.

Although other research has drawn attention to users' difficulties in understanding STHW displays (Caird & Roy, 2008), this research goes considerably further in analysing householders' interactions with such devices; it contributes to a more nuanced understanding of STHW-users (as summarised in Section 7.6) by generating a typology based on frequency of interactions with feedback and the degree to which this feedback subsequently shapes actions.

[114] Also advocated by Bergman (2013) in a review of domestic renewable heat technology

Category	Frequency of interaction with feedback	Reliance on STHW system in summer	Seasonal pattern of heating No. of modes	Use of feedback	Accessibility and intelligibility of monitor	Feedback most utilised	Number of interviewees in category*
I	Frequent	√	High flexibility & no fixed pattern	Influential on daily basis	High	Temperature of liquid returning from panel & thermal feedback from tank	1
II	Frequent	√	3	Mainly to satisfy curiosity but influential around switch-over time	High	Temperature of liquid returning from panel	2
III	Frequent	√	2	As for II above	High	As above	2
IV	Infrequent/ seasonal	√	2	Restricted to being influential around switch-over time	High to medium	As above	3
V	Minimal/ absent	X	1 or 2	Not influential	Low	None, except auditory feedback in one case	6

*** Unknown for one householder who had recently moved in**

Table 7.2. Characterisation of STHW-user categories

7.4.3 ASHP

In contrast to STHW systems (which complement rather than replace conventional heating systems), ASHPs replace conventional systems and constitute the main form of space and hot water heating where installed. Feedback on the technology's performance occurs through the provision of these services, that is, the attainment of thermal comfort and hot water. It could be argued, therefore, that there is less of a need for dedicated feedback devices to monitor its functioning.

Three interviewees had ASHPs and, in each case, the only energy meter available was the electricity meter serving the entire house. The frequency of interaction with these externally-located meters varied; two interviewees checked their meters quarterly for billing purposes and the other checked it monthly to monitor consumption more closely:

> 'The reason why we do it as well is to see how badly or well we're managing, the kettle, the laundry, and try if it's getting a bit high maybe we won't do three loads of laundry, maybe one, and keep it a bit constant.' (ID817, ASHP)

Despite this householder's interest in monitoring consumption, he did not yearn for a dedicated ASHP meter and was content with current arrangements. The other two interviewees monitored household electricity consumption via quarterly electricity bills; one of these wished for sub-metering to enable him to track specifically the ASHP's electricity consumption:

> 'I think it would be nice to know what the actual heating system is using and possibly the hot water ...' (ID1023, ASHP)

He thought such a dedicated meter would enable him to quantify cost savings achieved through turning the thermostat down, enabling him to further engage with the ASHP and better manage household finances. The third householder also considered it would be interesting to measure the ASHP's electricity consumption, preferably via an accessible indoor meter.

So, for these three ASHP-users, there was no dedicated feedback device and thus there had been no potential for householders to be shaped by feedback that could be generated by such devices. Feedback on the technology's functioning occurs instead through the attainment of thermal comfort. The ways in which attaining thermal comfort has shaped the behaviour of ASHP-users has previously been examined in Section 7.3. The lack of any dedicated ASHP meter is not seen as a matter of concern, although two of the three ASHP-users thought it would be interesting to monitor its electricity consumption.

7.4.4 MVHR

Within the households researched, MVHR systems act as complements to conventional heating systems, rather than replacements, introducing a degree of redundancy into the design for *space* heating. Within homes built to high air tightness levels, the technology serves also a key function in delivering forced ventilation (Macintosh & Steemers, 2005; Zero Carbon Hub, 2012a; NHBC Foundation, 2013a); here, deactivating the technology can adversely impact indoor air quality and potentially health (Yu & Kim, 2012; Zero Carbon Hub, 2012a). In such homes then, the MVHR system serves both a redundant and non-redundant role in relation to its space heating and ventilation functions respectively.

Five interviewees had MVHR systems but only one had a feedback device which provided information on the technology's status. In most cases, the perception of the technology (as then translated into actions or conscious inactions) was shaped instead by the presence or absence of sensory forms of feedback. Based on householders' exposure to, perceptions of and shaping by sensory forms of feedback, three categories of householder are distinguishable.

Category I is comprised of those exposed to predominantly positive, sensory forms of feedback, either in the form of positive thermal feedback or positive feedback on freshness levels. The first interviewee in this category lived in a highly energy efficient house (meeting Level 5 of the CSH). He considered the MVHR system was evidently working due to the thermal comfort experienced; he had only needed to top-up with the gas central heating system for a couple of months in the year. He had recently noted that the indoor air was very dry and had needed to open windows more frequently to let fresh air in. Overall, he perceived the technology as working very well; consequently, he had not altered the initial 'Automatic' settings for the system nor interacted with the technology itself in any other way. So here, positive thermal feedback had led to a conscious decision on inaction. The other Category I interviewee also lived in a highly energy-efficient house built by the same developer. For her, the technology was also evidently working due to the thermal comfort experienced; she had only resorted to the gas central heating system when it had been 'really, really cold.' It was also clear that the system was working due to the heightened level of freshness she perceived when switching to the summer operating mode. She could also sense via air movements whether the technology was functioning, as checked by placing a hand near the air vents located throughout the house:

> 'In some of them it pulls *[the air]* up and in some of them it pushes it out.' (ID1154, MVHR & PV)

Additionally, a low level of noise acted as a form of auditory feedback on the system's functioning:

> 'There is a little hum, it's not really loud, and it's only downstairs.' (ID1154, MVHR & PV)

This householder was the only one provided with a portable feedback device which informed her of system faults (discussed further in Chapter 8). When the sensory forms of feedback alerted her to a possible problem, she referred to this device to establish whether a fault had been detected by it. In total, this householder made use of four forms of sensory feedback (thermal comfort, air movements, air freshness and low level noise) and a feedback device to help her establish, on an on-going basis, whether the technology was functioning and to inform her decisions on when to switch between winter and summer operating modes[115], which she did on a flexible basis. For Category I householders, sensory forms of feedback have led to positive perceptions of the MVHR technology. Consequently, householders had retained the initial set-up and appeared to use the system as intended by designers. The two householders in Category I relied on the technology to deliver space heating for most of the year and had experienced the efficacy of their system during this period. Here, the MVHR system's agency was enabled by, and distributed through, the mainly informal, sensory modes of feedback which were either passively experienced (thermal comfort, air freshness and noise) or actively engaged with (gauging air movements). The systems exhibited agency through their ability to cause householders to introduce new feedback checking routines (evident in one case) and/or altered dependencies on conventional space heating systems; the latter could be described as the intended agency from the perspective of designers.

Category II encompasses those that consider they have had insufficient positive feedback (sensory or otherwise) on the operation of their MVHR system. At the same time, they have not experienced any significant negative feedback, and thus have adopted a neutral stance.

[115] The winter mode increases internal temperatures whilst the summer mode helps to reduce internal temperatures and increase feelings of freshness.

One interviewee belonged to this category – he had little sense of how well the system was operating:

> 'I can't say I have any great concept of how well it works… As I say, it may be that we're not getting the optimum out of it – I'm not sure quite what we were expecting to get out of it. The other thing is I don't use the top of the house that much. I suspect it's the top of the house that will get the greatest benefit as warm air rises **…**' (ID424, MVHR & STHW)

This householder had 'absolutely no idea' where vents associated with the technology were positioned. No-one had told him the system worked best with closed windows (NHBC Foundation, 2013a) and therefore windows had just been opened and closed as they would have been in a conventionally heated home (a finding commented on elsewhere (Macintosh & Steemers, 2005; Stevenson & Rijal, 2010)). He remembered to switch the system between summer and winter operating modes but this switch-over did not seem to be driven by any feedback received from the indoor environment. The MVHR unit was located in the attic and there was no perceptible noise associated with the system. At the outset, there had been a slightly negative form of sensory feedback in the form of a 'slightly fishy smell', but this had since abated.

In contrast to those in Category I, this householder had not had any experience or feedback that served as an unequivocal demonstration of the capabilities of the MVHR system (a point raised by two other householders in this research through door-step conversations and in previous research reported by the NHBC Foundation (2013a)). The air tightness standard designed for this house (as determined by the Building Regulations) would have been significantly less than for dwellings built to Level 5 of the CSH (occupied by householders in Category I). The MVHR system's effectiveness was likely, therefore, to have been lower and consequently harder to discern. To summarise, this householder received no feedback (sensory or otherwise) on whether or how the MVHR system was operating. Therefore, his actions were not actively shaped by any such feedback and his perception of the technology was fairly neutral. Although the MVHR system had exhibited limited agency in that the householder switched twice yearly between summer and winter modes, this action was not driven by any form of feedback but to knowledge gained elsewhere (possibly via instruction manuals or advice).

Category III includes those that have been exposed to predominantly negative sensory forms of feedback emanating from their MVHR system. For these interviewees, the unwelcome feedback consisted of unacceptably high noise levels which shaped their perception of the technology to such an extent that it led to the technology's reconfiguration or disconnection. The following quote recounts the conversation that took place between a site manager and the first of these interviewees when moving in:

> 'And I said: 'But it's so loud, I won't be able to sleep at night.' He said it's to do with the ventilation but he sort of made it sound that it's to do with the heating as well, the whole thing. And I said: 'There is absolutely no way in a million years I will be able to sleep with that on'. And I'll give you a demonstration – it was unbelievable. So he said: 'There's the switch.'... Now I just switch it on if anybody uses the shower. ' (ID805, communal biomass, CHP & MVHR)

Within this householder's duplex dwelling, the MVHR unit had been installed within an airing cupboard near the main bedroom. Due to the householder's action, the system's usage had been reduced to one of functioning as a basic extraction system on a very limited basis when showering took place, and then its use had to be manually activated by a switch in the cupboard. In effect, the system was disconnected and could not serve its initial heating or ventilation function. Here, the immediate negative feedback experienced led to the formation of a highly negative perception of the technology, which in turn shaped the householder's prompt actions in effectively disabling it.

A couple living in the same development as the previous householder had a similar experience with their MVHR system:

> '... if you went to our bedroom, the en-suite, it sounds like a jumbo jet is landing, trying to get the brakes on to land... Anyway, it was impossible to live with – I'm sure *[my partner]* will show you, you just couldn't sleep. So we got somebody in ... and they disconnected it and then had it connected so that when you switched the light on to go to the loo or do your cooking it turns on.' (ID804, communal biomass, CHP & MVHR)

This couple also had the MVHR unit installed in an airing cupboard near their bedroom and they soon concluded it was 'impossible to live with' due to the noise. The developer had stated that the system would improve the feeling of freshness in the home, but they had not perceived this:

> '... he said we have to keep it on all the time because it was for the good of the whole flat, for taking out the dampness, circulating the atmosphere ...' (ID804, communal biomass, CHP & MVHR)

They had the system re-configured so that it only came on when the toilet, kitchen or bathroom lights were switched on; thereby, significantly curtailing its operating time. The householders had noticed a potential consequence to this action in that the windows now had ‘got some dampness on them’[116]. In this example, the negative auditory feedback experienced led to a highly negative perception of the technology, which resulted in the householders reconfiguring the system. As with the first example, the need to ameliorate the continual negative feedback outweighed any promise of benefits from the technology.

The third householder within this category was spoken to during the hand-delivery of his questionnaire. He explained that he had switched off his MVHR system as it was too noisy and appeared to make no difference to indoor temperatures. Again, a combination of negative auditory feedback and the absence of any positive thermal feedback, led to a negative perception of the technology that caused the householder to disconnect it.

In this third category, the MVHR system’s agency is enabled by, and distributed through, one dominant form of negative sensory feedback. The system exhibits agency through its ability to cause householders to reconfigure or disconnect it; this could be described as an unintended agency from the designer’s perspective. In such cases, the technology could be considered as having failed its trial and householders consequently select to dissolve their association with it (Lehtonen, 2003). The issue of noise from MVHR installations (van der Pluijm, 2010; Yu & Kim, 2012) and the range of perceptions there may be on this, even within the same development (Macintosh & Steemers, 2005), has been observed in previous research. The prospect that MVHR systems may become disconnected due to dissatisfaction caused by noise levels is predicted by the NHBC Foundation (2013a) and evidenced by this research. In Monahan’s (2013) research, a MVHR system was decommissioned for a different reason - the unacceptable draughtiness it induced.

To summarise, this research has provided a more nuanced understanding of MVHR-users by generating a three-point typology based on their exposure to, perceptions of and shaping by sensory forms of feedback, with only one householder having a mechanised feedback device. I now turn to the last technology considered in this section, PV systems.

7.4.5 PV

Four interviewees had PV systems. Based on the frequency with which feedback was sought on the technology’s performance and the degree to which actions were subsequently shaped by this feedback, householders can be assigned to one of three categories.

[116] This may have been caused by insufficient ventilation (NHBC Foundation, 2013a).

At the most interactive level (Category I) two interviewees sought weekly feedback which influenced actions on an on-going basis. In both cases, feedback was obtained via electricity generation meters located in accessible, frequently-used spaces:

> 'Well, I am amazed under what poor light conditions it still generates electricity. I'd look at it if I go into the garage, which is quite frequently because it's an integral garage.' (ID240, PV & STHW)

> 'So we have this meter as well – this one is how much the solar panel generates … You can see on the meter that it goes up … it's probably generated about 10 kWh today *[25th February].*' (ID958, PV & STHW)

In addition to weekly checks, one householder was also making monthly comparisons:

> 'The first month *[December]* it generated 50 kWh, which is next to nothing, and obviously if it didn't generate more than that there was no reason to install it. But then the next month it generated 100 kWh … So it's generated just under 90 kWh now, and we still got 20 days until the end of the month *[February]*, so it's probably going to do 150 kWh.' (ID958, PV & STHW)

Further feedback information was available but unutilised:

> 'The inverter has got a multi-function panel on it. You can just key away through that and it will tell you *[an instantaneous generation figure as well as an accumulative figure*].' (ID240, PV & STHW)

In addition to the meters, there was also a light which indicated the PV systems were generating electricity:

> 'It's got lights which are on when it's generating – there's a green light … When it's not generating, the light just goes out.' (ID240, PV & STHW)

> 'I can see that the counter is going up and there is a light that's flashing outside as well ...' (ID958, PV & STHW)

Dependent on the electricity quantities being generated, both households made an effort to shift certain electricity-consuming activities to the hours of generation:

> 'Well, if it's a bright day and we're generating loads of electricity, we will run the dishwasher and the washing-machine in daylight hours.' (ID240, PV & STHW)

> 'We still think about it a little bit, and then you know if we have visitors in the evening and it *[the dishwasher]* gets filled up, then we would still do the dishwashing in the evening. But when we can, then we try to do it during day hours.' (ID958, PV & STHW)

This last household also shifted the usage of the washing-machine, whenever possible, to sunlight hours, as facilitated through using a built-in timer (which the dishwasher did not have). Although keen to undertake this degree of load-shifting, the householder notes:

> 'We are trying to use it *[the generated electricity]* as much as we can but it also needs to make sense.' (ID958, PV & STHW)

This comment signifies that the householder is aware that, although there is 'elasticity within their lifestyle for change' (Hobson, 2006a, p. 329), there are limits to this. This case also illustrates how the incorporation of timers into household appliances facilitates the ease and extent to which load shifting can occur (as noted by Munzinger, et al., 2006). For both households mentioned, the PV system served as a sunlight-dependent 'temporal lever' (Nye, Whitmarsh, & Foxon, 2010, p. 707), providing a sufficient incentive for the rescheduling of appliance usage. Here, the PV technology exhibited agency through its ability to temporally order specific user activities, the timing of which was guided by feedback from PV meters and weather observations. Such instances of load shifting have been noted in other studies (Section 3.6). For instance, Munzinger et al. (2006), in their large-scale survey of 229 PV-users (in retrofitted and new homes), established that 24% had exhibited some form of behavioural change and most of these had shifted the time at which certain appliances ran. Ghanem (2008, p.180) refers to such load shifters as 'opportunistic users'[117].

Both households in Category I moved into STHW-fitted homes. Both then proceeded to promptly install PV panels, motivated by the financial gains to be made through the FIT; as regards the PV technology then, they are active retrofitters. Each household reports an accumulative generation figure (possibly every 6 months) to the utility company and subsequently receives a financial form of feedback via the FIT[118]. This constitutes then a more formalised, infrequent interaction with meter readings, from which their FIT-based payment is calculated. The two Category I interviewees represent examples of year-round, influential interactions with feedback devices which shape behaviour on an on-going basis (in terms of the potential for daily load shifting in electricity-consuming activities). There is also an interest in tracking on-going financial gains.

In Category II, frequent feedback was sought but this did not appear to further shape householder behaviour. The one interviewee in this category moved into a PV-fitted home. He regularly checked the generation meter in order to gauge expected gains through the FIT, which had earned him £2500 the previous year. The PV meter was located outside and there was a further unidentified meter in the attic. Feedback on electricity generation had not,

[117] The term 'opportunistic user' is, however, also used by Ghanem (2008, p.180) to encompass those who exhibit a rebound effect by introducing the use of additional electricity-consuming appliances, over and above what they would have used before. This effect was not noted with PV-users in this research.
[118] The FIT payment made is derived from the electricity generation figure and an estimation of the proportion that is exported to the grid (50%) as opposed to being consumed on-site.

however, driven him to maximise savings through load shifting; he did not consider that it was his household's responsibility to change their behaviour given that others in the country were not doing so. This interviewee represents an example of year-round, inquisitive interactions with a feedback device which does not lead to any additional behaviour change. The interactions are driven purely by an interest in gauging on-going financial gains, rather than maximising them.

The householder assigned to Category III had been precluded from accessing any day-to-day feedback on the PV technology through the development's design. This interviewee had a shared-ownership arrangement with a housing company that had sole access to the technology, including the generation meter. The latter was located in a locked, brick-built hut in the development's communal car park, along with generation meters for the development's other PV installations. Although the development was over a year old, it was not yet clear to residents what share they would receive of monies obtained via the FIT, which would be initially received by, and managed through, the housing company. The householder interviewed thought that they would get a few pence per kWh off their normal electricity rate, but that the housing company would be reaping the bulk of the FIT payment. The lack of any day-to-day feedback on the performance of the technology, together with confusion as to how she would financially benefit from it, meant that this householder was receiving no encouragement or incentive to alter the timing of her electricity-consuming behaviour. Due to work patterns and demands on her time, she did not consider there would be much scope anyway for changing the timing of her electricity consumption. In addition, the electricity charges were currently deemed reasonable:

> 'I work all week and I can't *[change my behaviour],* I wouldn't think like that, because the electricity anyway is working out so cheap, £18/month, that I think that's pretty good. If it was more than that, then maybe I would think: 'Oh, I need to reduce … where and when I use my electricity.'' (ID1154, MVHR & PV)

The interviewee in Category III represents an example of someone who has been intentionally precluded from interacting with feedback devices and who was also unlikely to appreciably benefit financially from the technology, although the exact arrangements were unclear. The absence of any feedback meant that there had been no opportunities to be shaped by any such feedback. Haggett & Ghanem (2009, p.10) note from research undertaken on PV-users that 'energy consumption and engagement is directly correlated to design'. For the interviewee in Category III, the structural and organisational arrangements in place had certainly precluded her engagement in that she could not view the generation meter or any other feedback device, she had no responsibility for the installation and she did not appreciably benefit from the renewable electricity generated. In comparing householders from Categories I and III, it is evident that the latter had been 'excluded from the possibilities of particular forms of engagement' (Walker & Cass, 2007, p. 466).

To summarise, PV-users were assigned to one of three categories, dependent on interactions with feedback and the degree to which actions were shaped by such feedback. At the most interactive level, there were year-round, influential interactions with feedback devices which shaped behaviour on an on-going basis, in terms of the potential for daily load shifting in electricity consumption. At the least interactive level, a householder had been precluded from receiving any feedback on the technology's performance.

In Section 7.4, I have examined how householders engage with feedback from their LZC technology and whether this influences their actions. In so doing, I have revealed the predominant modes of formal and informal feedback associated with four technology types. These modes of feedback are significant as it is partially through these that the technology's agency is enabled and distributed. Such agency, as shown, may be intentional or unintentional, as viewed from the designer's perspective; furthermore, the agency may prove positive or negative in terms of the technology achieving its CO_2 reduction potential.

7.5 Certain pivotal events within the domestication process

7.5.1 Introduction

As presented within Chapters 6 to 9, this research generates insights into how certain events, or trials, may significantly influence the development of LZC technology-householder associations. I label such events as *pivotal events* and these are discussed in Section 10.6. In this section (Section 7.5), I highlight two types of pivotal events not covered elsewhere in Chapters 6 to 9; that is, holidays and the research process. It was observed that going and coming back from a particular holiday had a determining effect on domestication processes within two households, as discussed in Section 7.5.2. The influence of this research itself on domestication processes was also observed, as explored in Section 7.5.3.

7.5.2 Demonstration of capabilities

For two interviewees with STHW systems, a demonstration of their technology's capability was only enabled through a discontinuity in household routines, which in both cases was associated with holiday arrangements. In the first case, the householder had gone away for five weeks, returning in early April, and in preparation for this holiday had switched off the conventional water heating system:

> ' … we went away and before we went I switched the hot water off as one would with the boiler and then of course we forgot about it. And we came back and we'd been away for five weeks and we thought: 'Hmm, it would be nice to have a shower'. So I switched the shower on and had a piping hot shower and my wife had a jolly nice soak in the tub. Then our grandchildren came over in the evening; they had baths and what have you and suddenly I thought: 'Gosh, this hot water has been switched off for five weeks.'' (ID240, PV & STHW)

Prior to this holiday, the gas boiler had heated the water morning and evening and, since moving in in September, they had not contemplated either relying on the STHW system or limiting boiler usage to once daily. After the recounted event, the householder became sensitised to the technology's capabilities and reduced boiler usage to mornings only during the remainder of the warm, dry spell that April. The interview took place in April, so the householder's dependence on the STHW system in summer-time cannot be commented on, though he stated he would be experimenting with the technology as the weather warmed.

In the second case, the householder moved in in October and holidayed in February. In preparation for this, he switched off the immersion:

> 'I went away for a holiday, I think skiing in February, and when I came back I forgot to turn the electrical power water heater back on. So, for about three months – May, June and July - I didn't realise I hadn't got the electrical power switched on for heating water. It was all being powered by the sun. Fantastic and I didn't realise.' (ID826, STHW)

Prior to the holiday, this householder had not contemplated testing the technology's capability and had operated the immersion constantly. Once the technology's potential had been made apparent through the incident described, he continued his reliance on it, this time knowingly, until mid-August/September.

For both these householders, the demonstration of the STHW system's capability was only enabled through a discontinuity in the relevant household routine, which in both cases was triggered by a holiday arrangement and a fortuitous oversight in not re-activating the conventional water heating system immediately on their return. Thus, unintentionally, these householders became reliant on their technology for the first time and this enabled it to demonstrate its capabilities to them. This demonstration, or 'trial' (Lehtonen, 2003, p. 364), reshaped the householders' expectations of their technology and introduced a degree of sensitivity and variability into whether and how much they then used the conventional water heating system. This exemplifies how an embedded routine (transferred unquestioningly from previously experienced domestic settings) was brought into 'reflexive consciousness' (Southerton, 2013, p. 340) and adjusted to reflect better the specific socio-technical setting within the new dwelling. The technologies were also reshaped as their prominence increased; they were incorporated into amended household routines; and, when switching off or reducing usage of conventional water heating systems, they were enabled to perform better[119]. In relationship terms, the association between householder and LZC technology evolved from a disengaged state to a more dynamic, engaged one.

As discussed in Section 3.4, the effective use of a new technology may be thwarted by the dominance of 'more robust existing associations' (Harty, 2010, p. 313). In these two instances, existing associations refer to those which householders were familiar with; the householders had transferred their established routines involving conventional water heating systems from their previous home to their current one, and the STHW system had not actively figured (from the householder's perspective) in the socio-technical network that provided hot water. Through an unintentional break in established (or 'robust' (Harty, 2010, p. 313)) associations, the technology had the opportunity to demonstrate its capabilities and thereby enrol householders into a more engaged association with it. Via these pivotal events, an unintentional break in existing associations[120] enabled the technology to exhibit agency, and thereby become more fully enrolled in the reconfigured socio-technical network serving hot water needs. I now turn to the other pivotal event covered in this section - involvement in the research process.

[119] A greater proportion of solar energy can be absorbed by the STHW system's circulating fluid if it has not been pre-heated by other energy sources (Boait, 2008; Hill, Lynch, & Levermore, 2011; EST, 2011b). Additionally, if the tank water is unheated, the storage capacity for solar energy is maximised (BRE, 2008).

[120] Which could also be viewed as a break with a 'lock-in' behaviour (Bergman & Eyre, 2011, p. 342).

7.5.3 Involvement in the research process

A number of interviewees made reference to the research's impact on their association with their LZC technology. In one case, the impending interview had prompted a couple to seek out the STHW instruction manual and read it for the first time since moving in four years ago. Consequently, they established that their technology had not been maintained as recommended and they were planning to make arrangements for its first service. This household included the chair of the Residents' Association and he thought he might raise the previously undiscussed subject of the STHW installations and their maintenance.

Another householder, who had no instruction manual for her STHW system and had been unconcerned about maintenance issues, was surprised to learn during the interview that the technology might benefit from servicing. As a result, she intended to contact the installer to check on maintenance requirements. In this way, the interview had triggered a more attentive association with the technology.

In two further cases involving STHW systems, the interviews led householders to question their year-round use of conventional energy systems for hot water provision. In neither case had householders tried to rely on their technology in summer-time, either because they had not got round to experimenting (the first quote) or because they had been advised to keep their conventional system on (the second quote):

> 'No, I haven't tried it. I guess it's probably at the back of my mind with every other thing I have got to do, just put it on one side and think I probably should do that. And then it goes out of my mind ...' (ID256, STHW)
>
> 'No, it's really interesting actually, that was worth coming just for that; it's made me think about what I'm doing.' (ID424, MVHR & STHW)

For the last householder quoted above, the basis of his routine and its consequences had been brought to the fore and questioned. He thought that his non-interactive stance with the technology might now change as a result of the interview, as this had given him 'things to think about.' As with the first householder mentioned in this section, involvement in the research process led this householder to envisage a different future with his technology.

For certain householders, the interviews provided a dedicated time during which aspects of the LZC technology and their experiences with it could be discussed at length, sometimes for the first time. For example, at the end of an interview with one householder, who had had a particularly disengaged association with his STHW system for four years, he stated:

‘I’ve thought about it more than I’ve ever thought about it before.’ (ID295, STHW)

During the 26 interviews, I was able to relay to householders how other interviewees interacted with the same type of technology. Through this facilitated form of benchmarking, the householders were able to compare their behaviour to others and to establish what might be construed as better or best practice, in terms of optimising the technology’s operation and maintaining it; in this way, information imparted during the interviews became part of the informal distributed inscription (Section 3.4) for the technology. In effect, the research process brought the LZC technology temporarily into the foreground for the householders involved[121], firstly through completing the questionnaire and secondly via the interviews.

This discussion has illustrated how an involvement with the research was likely to have a shaping effect on certainly some interviewees[122], triggering longer-term shifts in technology-householder associations towards further engagement. In this way, the research can be seen to extend beyond an act of inquiry, in that it also contributed to the on-going development of domestic socio-technical associations, a finding echoed by other human geographers such as Hobson (2006b). These findings support the view that research is a ‘performative practice that contributes to shaping the world we come to live in’ (Cameron & Hicks, 2013, p. 2), although any shaping may remain relatively limited across space and time unless research findings are effectively disseminated.

7.6 Conclusions

The purpose of this chapter was to describe and appraise how householders come to use, regard and interact with their technology and, in so doing, identify key determinants responsible for the progressive shaping of LZC technology-householder associations.

In Section 7.2, I started by demonstrating the distributed nature of the inscriptions householders utilise to help them understand their technology. Such information has been derived previously for occupants of PV-fitted homes (Munzinger et al., 2006), but this research extends the range of LZC technologies considered. I introduced the concept of *formal* and *informal* inscriptions to distinguish between the information sources initially provided to

[121] Promoting a form of ‘discursive consciousness, making participants reconsider what they do, and why’ (Hobson, 2003, p. 104).
[122] This shaping potential of interviews is discussed by Patton (2002, p.405), who refers to them as ‘interventions’, whose primary purpose is to obtain research data but which may also lead to transformations due to the ‘reflexive’ processes involved.

householders on moving in and others sources to which householders turn for assistance. The instruction manual and home user guide constitute the formal inscriptions handed-over initially and they are referred to by 61% and 35% of the 122 householders surveyed, respectively. The range of informal inscriptions is comprised notably of information from installers, maintenance companies, neighbours and the internet. 11% of surveyed householders had never referred to any information source, despite half of these expressing interest in their technology.

In Section 7.3, I examined how householders are configured by the design, placement and settings of LZC technology. I looked at the ways in which different technologies (STHW, ASHP and MVHR systems) are arranged within the home and how these arrangements, together with the initial technological settings, variously shape the nature of householders' interactions. For STHW systems, I identified how the low visibility, inaccessibility and perceived complexity of component parts may hinder householders' interactions. I found that certain householders will not question or feel sufficiently confident to alter initial settings for their conventional water heating systems, partly due to a belief that they have been set up to optimise gains from the STHW system. This finding emphasised the importance of installers selecting appropriate initial settings. For ASHPs, I found that householders' actions were primarily shaped by the technology's more limited space heating capabilities, as caused by its inherent design and the associated lower temperature of distributed water. This forces a change to previously adopted heating patterns, whereby, in order to attain customary day-time thermal comfort levels, ASHPs need to be continuously run. Householders were seen to avoid seemingly complex and unreadable programmers in favour of simpler thermostats as the primary control mechanism. For MVHR units and associated controls, their typical siting in unfrequented places configured householders as passive users of this technology. In one exception, the placement of controls in a frequented, ground floor location enabled a flexible, interactive association to develop wherein the householder became effectively enrolled in the technology's operation. I highlighted how the general 'hands-off' design approach, whilst potentially preventing unintentional tinkering, can backfire when someone moves into a home where the technology has either not been activated by the developer or has been deactivated by the previous occupant. In such situations, the MVHR system may remain dormant long-term. In addition, the 'hands-off' design approach does not appear affective in preventing those who find their installation's noise levels intolerable from reconfiguring or deactivating it. By attending to three technology types, I have illustrated the different ways in which interactions are influenced by design, placement and settings.

In Section 7.4, I focused on what LZC technology-related feedback householders engaged with and whether this influenced actions. I incorporated a consideration of the feedback content and the positioning of feedback devices (monitors and meters). Four technology types (STHW, ASHP, PV and MVHR systems) were examined to highlight the various ways in which users became shaped by formal and informal modes of feedback. For STHW systems, I contributed to a more nuanced understanding of the frequency with which householders interact with feedback and the degree to which this feedback subsequently shapes actions, through developing a five-point typology.

Nine out of 15 interviewees interacted with STHW feedback devices and relied on the technology to varying degrees. In the most interactive category, a householder had year-round, influential interactions with feedback which shaped behaviour on an on-going basis, in terms of the potential for daily adjustments in immersion usage. Here, the STHW system's on-going agency was enabled by, and distributed through, the formal and informal modes of feedback with which this householder chose to engage. For these nine interviewees, the STHW system exhibited agency through its ability to cause householders to introduce new routines that revolved around checking informal and formal modes of feedback, with varying frequencies, and changing the seasonal dependence on conventional water heating systems accordingly. However, there was no evidence that any interviewees tailored the timing of hot-water consumption to the availability of solar-heated water. If supplies of solar-heated water were insufficient to meet instant demand, it appears that conventional hot water systems were activated rather than deferring hot water-consuming activities until sufficient solar-heated water was generated. Thus, it is concluded that for 60% of interviewees, the STHW systems exhibited agency through their ability to cause householders to introduce new feedback checking routines and altered dependencies on conventional water heating systems; however, the STHW systems have not demonstrated an ability to temporally order the interviewees' hot water consuming activities as no incidents of load shifting were evident. There was some limited evidence of load shifting, however, from the wider population of surveyed householders; within the returned questionnaires, three STHW-users had provided written comments that revealed a degree of load shifting was taking place.

The findings from this research contrast with research on STHW retrofitters (Caird & Roy; 2008), where 47% reported evidence of load shifting, supporting the view that active installers of STHW systems are unrepresentative of the wider population in their degree of commitment to these technologies (Rohracher, 2003).

In the least interactive category (containing six out of 15 users), interviewees rarely, if ever, checked the monitor, which was viewed as inaccessible or indecipherable. Here, the absence of engagement with feedback appeared to curtail the technology's ability to exhibit agency; in each case, dependence on conventional water heating systems continued and therefore householders never received any unequivocal demonstration of their STHW system's capabilities. For a number of these householders, ceasing dependence on conventional water heating systems had not been contemplated as they were unaware that this might affect the STHW system's performance and their ability to save on energy costs; in other words, the act of switching off conventional water heating systems in summer-time had not constituted common sense. A common view amongst those in this least interactive category was that they would benefit from more informative feedback, such as knowing what proportion of their hot water needs were being met by the technology. In contrast, those who relied solely on their STHW system for periods of time had experienced its efficacy.

For ASHPs, no dedicated feedback devices were made available and feedback on its functioning occured instead through the attainment of thermal comfort. For MVHR systems, I contributed to a more nuanced understanding of users based on their exposure to, perceptions of and shaping by sensory forms of feedback (only one household had a mechanised feedback device). Here, the technology's agency was enabled by, and distributed through, these sensory modes of feedback which the householders either passively experienced (thermal comfort, noise, air freshness) or actively chose to engage with (gauging air movements). Where perceptions are positive overall, householders appeared to make use of the system as intended by designers. Systems in this category exhibited agency through their ability to cause householders to introduce new feedback checking routines (evident in one case) and/or reduced dependencies on conventional space heating systems; the latter could be described as the intended agency from the perspective of designers. Where perceptions are predominantly negative due to noise, householders selected to reconfigure their MVHR system to severely reduce operating times or to disconnect it entirely. Here, the technology's agency was enabled by, and distributed through, one dominant form of sensory feedback – noise. The systems exhibited agency through their ability to cause householders to reconfigure or disconnect them; this could be described as an unintended and negative agency from the perspective of designers.

For PV systems, householders were assigned to one of three categories, dependent on interactions with feedback and the degree to which actions were shaped by it. At the most interactive level, there were year-round, influential interactions with feedback devices which shaped behaviour on an on-going basis (in terms of the potential for daily load shifting in electricity consumption). PV systems in this category exhibited agency through their ability to cause householders to introduce feedback checking routines and load shifting. The second category was characterised by year-round, inquisitive interactions with feedback devices which did not additionally shape behaviour but were driven by an interest in the financial gains to be made. The PV system in this category exhibited agency only through its ability to cause the householder to introduce feedback checking routines. The third category was comprised of a householder who had been precluded from receiving any feedback on the technology's performance and who had therefore not had an opportunity to be shaped by any such feedback.

By considering four technology types in Section 7.4, the research demonstrated the different modes of informal and formal feedback that may be associated with each technology type. These modes of feedback are significant as it is partially through these that the technology's agency is enabled and distributed. Such agency, as shown, may be intentional or unintentional, as viewed from the designer's perspective.

In the penultimate section of this chapter, I introduced the notion of a 'pivotal event' as one which triggers householders to shift and re-stabilise their association with their LZC technology, and two types of such events were discussed. For the first type, an unintentional discontinuity in household routines (associated with holiday arrangements) enabled the technology to demonstrate its capabilities. This experience prompted two households to reduce their dependence on conventional water heating systems, signifying a conscious enrolment of STHW systems into the socio-technical network configured to serve hot water needs. For the second type, involvement in the research process presented a dedicated time in which to think and talk about the LZC technology. The research process constituted an intervention that enabled the circulation of pertinent information, derived from this research and elsewhere, to householders. Both types of pivotal events destabilised and triggered shifts in prevailing LZC technology-householder associations towards further engagement, through altering the ways in which householders viewed (objectified) and used (incorporated) their technologies. Both types of event triggered, or are expected to trigger, delayed trials of the LZC technology (discussed in Section 3.4).

A further type of pivotal event, constituted by certain conversations between householders and those repairing their LZC technology, is identified in the next chapter on maintaining and repairing LZC technology.

Chapter 8: Maintaining & repairing LZC technology

8.1 Introduction

At the end of the last chapter, I examined how certain events had significantly influenced the development of specific LZC technology-householder associations; such pivotal events emerge again in this chapter's discussion on the maintenance and repair of LZC technology. Chapter 7 also highlighted the variable degree to which householders interact with, and respond to, informal and formal modes of feedback from their technology. This diversity in technology-householder associations is also apparent when examining maintenance and repair processes. As for the previous chapter, certain factors that contribute to this evident diversity in outcomes are revealed.

I commence this chapter by evaluating the prevalence of faulty installations and find that these are a relatively common occurrence, the causes of which are discussed (Section 8.2.1). Given this prevalence, I proceed in Section 8.2.2 to consider how both householders and technologies are shaped by the processes of repair and how such processes impact on the on-going development of technology-householder associations. The topic of maintenance is researched in a similar manner; I start by evaluating the prevalence of maintenance activities and the factors that hinder and promote this (Section 8.3.1). The NHBC Foundation (2011b) has highlighted the need for a greater understanding of issues pertaining to the maintenance of LZC technology, such as whether householders know what maintenance is recommended. This section addresses such issues. I then proceed to consider how householders and technologies are shaped by the maintenance undertaken (Section 8.3.2). The main findings from the chapter are summarised in Section 8.4.

Through the discussion, the following four research questions are addressed: *what is the prevalence and cause of faulty LZC technology and how do these faulty installations come to light (Section 8.2.1); to what extent are LZC technologies maintained and what are the underlying reasons for this (Section 8.3.1); has any on-going communication been received or feedback sought in relation to the LZC technology (Section 8.3.1); and, what are the wider benefits of maintenance processes (Section 8.3.2).*

8.2 Faulty installations & the processes of repair

8.2.1 What is the prevalence & cause of faulty installations?

One of the common themes emerging from the research was faulty LZC technology. In this section, I explore the prevalence and potential causes of these faults, and the processes by which these come to light. Out of 26 interviewees, 15 drew attention to faults experienced; these cases are subdivided for discussion purposes into those where faults are likely to have been present from the outset and those where faults may have subsequently developed[123].

Approximately one third of all interviewees *moved in* with faulty technology and sometimes this was promptly detected; in one case, a flat had remained empty for six months after completion but the STHW system had been active during this period:

> 'The flat was empty; no-one was using it *[the STHW system]*. They are immensely efficient … so it just got so hot that it actually broke. So they had to go and fix it then.' (ID155, STHW)[124]

In another example, the STHW system's temperature-control function was promptly identified as faulty:

> 'What happened was that somehow it managed to overheat, and all the insulation on the hot water pipe coming down through the roof into the hot water tank, didn't burn off, but it scorched off. So the whole system was over-heating. Whether this was a circulation problem or lack of monitoring on the roof, I don't know.' (ID312, STHW)

Where householders are reliant on the technology for the provision of a certain service, it soon becomes evident if it is working unsatisfactorily:

> 'When I first moved in, the radiators weren't heating up very much and there was a pressure difference problem across the input and the output of the heating system… I was initially noticing that the temperature was dropping during the times when everybody's system was beginning to come on by default.' (ID608, CHP)

Although these householders promptly established their installation was sub-standard, others took up to a couple of years to do so. There were several reasons noted for these delays, the first being that performance levels were not noticeably influenced and effects from the faults took time to build up to discernible levels, as for the following example:

[123] This distinction is hard to ascertain with certainty in a number of cases.
[124] A similar case where a STHW system fault was caused by under-use was observed by Bell et al. (2010).

> 'Water is dripping, but very slowly … seeping through the ceiling onto the wall, and next door had it as well. So they came round, replaced it and re-painted inside and according to the guy that came round to replace the pipe he said it was something to do with installation, when they put a nail through it or something ...' (ID1154, MVHR & PV)

Here, there was a minor but on-going leak from the condensate pipe attached to the MVHR unit in the attic. The occurrence of the same fault next-door pointed to an inexperienced fitter having damaged the equipment on installation.

A second reason for delayed fault detection arises where incorrectly configured systems operate satisfactorily for a period of time until a fault-induced event occurs:

> '… my pressure vessel in the hot water system failed, blew up, soaked my flat and the flat below. And I'm told it's because … they put the pressure vessel which is designed for a glycol circuit in the hot water circuit. What they said was the gland in there deteriorated in the hot water and that exposed the metal in the pressure vessel to the hot water, and the hot water degraded the pressure vessel within two years.' (ID826, STHW)

Here, the technology's components had been incorrectly configured, causing a key component to deteriorate over the two years before the incident occurred. This householder lived in a block of 19 flats and, as a result of this incident and poor performances from other installations, all 19 STHW systems were inspected and at least six had major faults; one system, for example, was allegedly plumbed in in-reverse[125].

In certain instances, manufacturers removed suspected faulty systems proactively before fault-induced events occurred:

> '… the manufacturer … sent us a letter last year saying there was a defect, or they had found a possible defect, with a part of it. As part of the warranty, because it was less than x years old, they would go and change it for us.' (ID817, ASHP)

> '… over a year ago now, *[the manufacturer]* called in some of their heat pumps. They had obviously had a problem with some of them and certain serial numbers they recalled.' (ID1056, ASHP)

A third reason for delayed fault detection can be partly attributed to householders not always knowing what to expect from their technology (for example, what discernible difference should MVHR systems make?).

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[125] This type of fault was also observed in two out of six new homes researched by Bell et al. (2010). Here, flow and return pipes were plumbed in in-reverse and this was stated as reducing the technology's effectiveness 'since the design of the panels and their control was geared to the specified flow direction' (Bell, et al., 2010, p.37).

The preceding paragraphs focused on householders who had moved in with faulty technologies. For others, faults appeared to develop post-occupation:

> 'I have had problems where it's leaked, so I do just quickly check the pressure is working and I've had a problem with the pressure gauge as well, it wasn't reading the pressure correctly.' (ID155, STHW)

> '… I opened the door and *[the STHW monitor]* is only registering ambient temperature and it didn't change. So, I phoned up the manufacturer and they said 'Ah, well, if it's only recording the ambient temperature, you've got something wrong with your sensor' … 'What happens is that birds pull the sensor out of the panel at the top and all the panel at the top is, is a copper tube with a thermocouple, and it's on a very thin wire which goes down to the controls, and a bird thinks it's a worm and it pulls it out.'' (ID312, STHW)

> 'We had a leak and it covered most of the things in the airing cupboard with anti-freeze and a nasty blue colour, but that was in its early stages.' (ID312, STHW)

> 'We've also had leaks. In fact, when they were finished restoring my panel, there were leaks so I had to get them back to do it up again. But at the end of the day, it seems to me that a lot of fitters haven't quite got an understanding of what they are doing.' (ID826, STHW)

> '… one of the questions is, well, these heat recovery systems keep going wrong, who's paying for it – is that going to come straight out of our maintenance, and is that right that it should come out of there? I would have thought the warranty on these things would have been a lot longer.' (ID1154, MVHR & PV)

The reported causes of faults varied and included operating technologies in empty properties; damaging parts during installation; incorrectly configuring parts; installing incorrect parts; omitting parts; deteriorating parts; escaping fluids and tampering by non-human agents (birds). The means by which faults came to light also varied. Predominantly, householders became aware of these themselves, but sometimes neighbours drew attention to the likelihood of a fault and, in a couple of instances, manufacturers proactively replaced technology considered potentially faulty.

The prevalence of faulty technology was not directly queried in the survey. How representative of the wider surveyed population were then the interviewees' experiences? The 26 interviewees represented 19 developments, in which seven had multiple households experiencing faults:

> 'People were saying: 'The water, it's not as hot as it was. I had a shower in the evening, the heating's not the same, why's it different?' Nobody knew, some people changed the heaters and found out that's what it was.' (ID295, STHW)

‘*[The repair work]* was done if we asked, or if somebody said: ‘Oh, we’ve had ours changed – don’t you think you should’ and so on.’ (ID312, STHW)

‘I think there were a few problems. Initially, a lot of people in the building had complained, said there was a pressure problem with the actual combined heat and power unit.’ (ID608, CHP)

‘Well quite a few people have brought them back regarding the system *[MVHR]*. I know of four of us, that’s all. The young girl over there brought them back because she didn’t think hers was working at all and another flat - they were getting other people’s cooking smells in their flat, and something had gone wrong with how they configured the whole thing.’ (ID804, communal biomass, CHP & MVHR)

‘… we thought we’d complain to the builders/developers, who brought in the experts, who then re-plumbed in, renewed and re-installed all 19 systems… Probably half a dozen at least, maybe more *[were found to be faulty]*.’ (ID826, STHW)

Householders from developments other than those represented by the interviewees also mentioned faulty or underperforming installations through the ‘Any additional comments’ section of the questionnaire:

‘It is rubbish – advert says: ‘Free piping hot water’ – Barely warms to 30^{o}C.’ (ID426, STHW)

‘I have experienced 2 major leaks from the system causing ceilings to collapse + other owners have had problems. The system is currently isolated and I would happily strip it out to give more useful storage space.’ (ID136, STHW - lives in a block of 12 flats)

Comments from interviewees and questionnaire respondents suggest, then, that faulty LZC technology is a relatively common occurrence. Faulty installations have also been noted in other studies; in one, the NHBC Foundation (2012b) stated that insufficiently trained installers were blamed for 90% of faults. Caird & Roy (2008, p.343) interviewed 15 STHW-retrofitters, of which 80% reported faulty installations. PV-users (in retrofitted and new homes) appear to fare better, with Munzinger et al. (2006) reporting that 30% of 239 users had experienced operational disruptions, of which only 6.7% required external assistance to resolve. In another report, this time on MVHR systems in new homes (Zero Carbon Hub, 2012a, p. 6), it was concluded that failures in ‘design, installation and commissioning practice are all too common’. Thus, the finding in this research that faulty LZC technology is prevalent concurs with previously published academic literature and building-sector reports.

8.2.2 How are householders & technologies shaped by repair processes?

Given the prevalence of faulty LZC technology as highlighted by the research participants, I proceed in this section to review the ways in which both householders and technologies are shaped by the ensuing processes of repair. For householders, the most common driver behind such shaping appears to be the content of conversations with repair persons. For some interviewees, encounters with these specialists constituted the first available opportunity to discuss their technology with a knowledgeable other, and four interviewees reported an increased engagement with their technology afterwards. The type of shaping engendered by these conversations can be characterised by the level of engagement that ensues. At the first notional level, householders gained an improved understanding of their technology:

> 'So how is this actually working as we don't have a particularly sunny climate – how does it work? And actually it's by UV rays I think, so that's why it works in cloudy conditions as well. So it's quite clever. And obviously when people come round to service it you end up talking about it… all the guys I've met have been immensely enthusiastic about it.' (ID 155, STHW)

> '… I've learnt a lot more from talking to them. We've had up to three people at any one time overlooking the system...' (ID826, STHW)

At the second level, householders received and followed guidance on how to operate their technology:

> '… when the plumber came I chatted to him about it *[the ASHP]* and he said: 'Yes, you are better to leave it switched on, regulate it as you want it with the thermostat because that way you keep an even heat, the building itself keeps an even heat and you haven't got to keep building it up and using a lot of extra fuel.'' (ID1056, ASHP)

> 'He had to re-set it and he actually showed me, and explained to me, how the different dials and so on worked.' (ID1056, ASHP)

Where guidance received concurred with how householders were already operating LZC technology, it reinforced the approach adopted. In the following example, a STHW-user had installed a timer onto his immersion to regulate its otherwise constant use, and this form of control was subsequently advocated by the repair person:

> 'I did it and then when the guy came round to top up, he recommended it.' (ID829, STHW)

At the third level of shaping, householders received and followed guidance on how to monitor the performance or status of their technology:

> '… they had to purge the system and get the water through, and I guess at that point you become a bit more of an expert about pressure, and water, and is the system working; you know you check the bar gauge to see whether there is sufficient pressure… they said this is how you've got to use it, just make sure the bar is at a one bar pressure ...' (ID 155, STHW)

The fourth and highest degree of engendered engagement was exemplified by someone who received and followed guidance on how to self-maintain his technology. Here, the householder had telephoned the installers, who had previously repaired his technology, for further assistance and they talked him through how to self-maintain his technology:

> '… there's two valves you have – I don't know why you have two – there must be some kind of reservoir or something to stop the pressure going straight away. You open one, then you open the other and you just wait for the bar to increase.' (ID155, STHW)

Via these four levels of engendered engagement, repair persons effectively enrolled householders further into the technology's socio-technical network and the information provided formed part of the *informal* distributed inscription (Section 3.4) pertaining to the technology. In these examples, the trials triggered by the faults reconfigured both householders and their technology, whereby the LZC technology-householder association developed and re-stabilised into a more robust configuration. In these instances, then, the increased engagement between the householder and the technology engendered by the repair person constitutes another form of pivotal event, as introduced in Section 7.5.

Rather than always furthering engagement, however, repair persons were seen on three occasions to promote instead a disengaged stance by STHW-users:

> 'If I think about it, the chap who came actually set the whole thing up, just said you don't need to look at it at all, it just looks after itself... I remember the chap saying you don't have to do anything.' (ID256, STHW)

Through such conversations, repair persons verbally black-boxed the technology, absolving householders of any responsibility for monitoring the technology's performance or maintaining it, effectively shaping them as passive users. In one of these cases, however, the only example of repair persons encouraging load shifting was noted (although the advice was not followed):

> 'I mean the recommendation from the fitter is that I should shower in the evening because then you've got a full days heat from the sun.' (ID826, STHW)

Shifting to a wider perspective, I now consider how the experience of dealing with faulty installations shapes householders' perception of their technology. For two interviewees, these experiences made them more comfortable with their technology – the ordeals (or trials (Section 3.4)) strengthened their knowledge of what could go wrong and the actions to take:

> 'I was really frustrated at the beginning: 'Ah this is just too much hassle, what the hell, you've got this red expansion vessel – what the hell is going to go wrong here?' 'is the pressure going to shoot up, is it going to go down, why doesn't it work?' Now it's just fine and I like it and it works.' (ID155, STHW)

Despite experiencing three faults with his technology, this householder was unconcerned about its future reliability as he now knew what could happen; he felt better prepared for future faulty eventualities. Through the processes of repair, he had learnt how to monitor and self-maintain his technology. Another householder also appeared satisfied with his STHW system, despite having experienced four separate faults:

> 'Now I have quite good control, I'm actually quite relaxed now. I have a safety valve and a safety temperature control in the system and they seem to be – there is a valve system too which wasn't working very well, that's been replaced as well. Happy with the technology, I'm keen to see it working, which I now can see.' (ID826, STHW)

Through the processes of repair, he had gained a better regulated, correctly configured system with which he felt comfortable.

For three other interviewees, however, the experience of faults and the processes of repair had increased their wariness, regarding the technology's on-going reliability and/or the cost of future repair-work. Certainly for the first example below, the householder had already envisaged an uncertain future for the technology:

> 'I think it has a limited life and I can imagine it breaking down and it not being worth replacing it …' (ID273, STHW)

> 'I was concerned about reliability, purely because we had had this problem with it tripping out by overheating the water ...' (ID1030, STHW)

> '… it's not just the routine maintenance, it's issues, the fact that they're stopping working, they're clogging up a few months after the filter has been replaced. I think that's why mine stopped working. You don't know which part of it is routine, you know, and which isn't. I mean I had this filter replaced before Christmas, so 6 months is a bit of a short time for it to block up again.' (ID1154, MVHR & PV)

For the remaining interviewees whose technology had required repair, their experiences did not appear to significantly influence their view of the technology, one way or the other:

> 'It's only had one problem, probably not too bad. It's a new technology and a new technology usually breaks down more frequently than an established technology but it seemed to be okay.' (ID295, STHW)

Thus, the experience of dealing with faulty installations can be seen to shape perceptions in divergent ways, from making householders more wary of the technology to making them more comfortable, and potentially more resilient to the impact of any future faults. In Caird & Roy's (2008) research on STHW-retrofitters, they observed how faults undermined users' trust in the technology, but did not comment on any users becoming more comfortable with the technology.

Having considered householders, I now turn to how LZC technologies are shaped in various ways by the processes of fault identification and repair, as surmised through analysing the interview transcripts. Firstly, shaping occurs through the rectification of physical faults and deficiencies whereby component parts become correctly configured; substandard parts are displaced by higher calibre counterparts; worn out parts are replaced; incomplete installations with missing parts become whole; operating fluids are replenished; unregulated installations become self-regulating and, at times, whole units are substituted. In addition to rectifying initial faults, once repairs are underway other faults sometimes come to light and are attended to; initial faults thereby act as triggers for more thorough reviews and services of installations. In addition, through neighbourly conversations (see also Section 9.3), initial faults may cause neighbouring installations to come under increased scrutiny. Consequently, faulty installations elsewhere in the development may become identified sooner than they otherwise would have been. The rectification of faults can therefore involve multiple components and multiple installations, extending the processes of repair beyond that initially envisaged.

The second and third forms of shaping are consequent to the physical upgrading of the technology and involve an improvement in the technology's performance (as it potentially proceeds to function in greater alignment with designers' intentions) and reliability levels (as repair persons reduce the probability of future fault-induced events by rectifying other previously concealed faults).

The fourth form of shaping arises if the technology's user becomes more engaged with the technology subsequent to the processes of repair. Such users may become more knowledgeable about, or more wary of, the technology. Any higher level of engagement may lead to improved modes of operating and enhanced monitoring for the technology (which may lead to earlier identification of future faults). Through becoming associated with more engaged users, technologies may therefore function better and be better safeguarded against future deterioration. In contrast, the fifth form of shaping of LZC technology arises when users become less engaged through the processes of repair. The disengagement of users (as encouraged via the verbal black-boxing of the technology by certain repair persons) isolates the technology from on-going monitoring and maintenance, making it vulnerable to future deterioration.

The sixth form of shaping arises when technologies gain a tarnished image. Within the warranty period, costs of repair may be fully or partially covered; beyond this period, however, an installation's lifespan may become influenced by the frequency of its historical faults. Once users begin to incur full repair costs, they may focus more on the costs and benefits of conducting repairs. If an installation has a chequered history of faults, this may lessen its perceived benefits and influence the decision on whether to continue to repair and operate it.

Finally, through the first instance of repair, LZC technologies become associated with repair persons. These transient associations can be re-invoked as necessary, facilitating quicker and more straightforward future processes of repair. Through these extended socio-technical associations, technologies become more manageable entities as users establish access to trusted sources of assistance.

To conclude, LZC technologies may be shaped in a number of ways by the processes of fault identification and repair, encompassing changes to their physicality, functionality, manageability, image and lifetime. So far in this chapter, I have confirmed the prevalence of faulty LZC installations (as noted in previous studies) and revealed the range of ways in which both householders and technologies may be shaped by the processes of technological repair (as summarised in Section 8.4). I now turn to the related topic of maintenance.

8.3 Processes of vigilance & maintenance

8.3.1 What is the prevalence of vigilance & maintenance & what are the influencing factors?

In this section, I go on to explore the prevalence of maintenance and related monitoring activities and factors that hinder and promote this. 12 of the 26 interviewees had never self-maintained their technology or had it proactively maintained (or serviced) by others, although some installations had required repair (and may therefore have received some form of servicing during this). Several reasons for this lack of maintenance were identified, the first being a lack of written guidance on maintenance requirements; in one case, no documentation was provided and in three cases the documentation did not cover maintenance requirements:

> ‘I’ve got no paperwork about the unit itself.’ (ID1056, ASHP)

> ‘There is no service guidance at all in the manual.’ (ID829, STHW)

Six further interviewees possessing documentation on their technology did not know whether this covered maintenance as they had never referred to it for this. This highlights a second factor; householders may not consult available documentation for maintenance advice:

> ‘I don’t know whether you’re supposed to get it serviced. I ought to go back and have another look in the user guide to see what it says about that.’ (ID424, MVHR & STHW)

> ‘There’s probably a part *[that says something about maintenance],* but I haven’t really looked at it.’ (ID817, ASHP)

> ‘I’m not even sure it warrants an annual inspection. I think it shows a spanner which says come and look at me. That’s about it. I’m not aware of anything. I’m not a manual reader I’m afraid … As far as I’m aware, it either works or it doesn’t.’ (ID1023, ASHP)

This situation was further illustrated by one couple who unearthed their STHW-manual in preparation for the interview, having lived in their home for four years:

> ‘Though this is the first time I’ve actually opened the manual. It just went into a pile with everything else when we moved in.’ (ID928, STHW)

Having now read the manual’s maintenance section, they were surprised to learn they should have been maintaining their technology:

> ‘It’s supposed to be serviced every two years with a full drain down every four years.’ (ID928, STHW)

They planned to get the system promptly seen to:

> ‘There is a contact number in the back *[of the manual]*; I guess we’ll just use the number it says in here.’ (ID928, STHW)

This couple had never solely depended on their technology, having run the immersion for four hours daily, year-round. Such householders, who do not ever solely depend on STHW systems (see Section 7.4), cannot reliably judge whether they need maintenance through any changes in performance, as they would not necessarily detect this. Another interviewee drew attention to a third factor:

> ‘We really haven’t had any information on how often anyone should come and check it. It’s been over a year now and no-one’s come …’ (ID833, STHW)

Excluding those who had centrally controlled LZC technology (such as CHP) or who co-owned their property with a housing company, only one of the remaining interviewees had ever received any contact from a third party in relation to servicing their technology. The preceding quote suggests that certain householders may be awaiting such prompts which have not been forthcoming. This third factor, then, pertains to a lack of contact from others (such as installers and manufacturers) regarding servicing.

In a couple of instances, non-maintainers appear to have been shaped by advice from repair-persons:

> 'If I think about it, the chap who came actually set the whole thing up, just said you don't need to look at it at all, it just looks after itself… so as far as I know I don't have to maintain it.' (ID256, STHW)

Thus, this fourth factor pertains to repair persons sometimes reinforcing a non-maintenance stance. A couple of interviewees in the non-maintainer category had previously tried or were currently trying to arrange for the regular servicing of their technology, but had experienced difficulties with doing so:

> '… what they were saying was: 'We're not issuing any more maintenance contracts – and sorry we can't come and repair your equipment', which I found most unsatisfactory … I can't find anybody who will take responsibility or issue a maintenance contract … these people are all very keen on installing this equipment, but nobody wants to take on the maintenance.' (ID312, STHW)

When this householder moved into his property, he did not immediately consider establishing a maintenance contract, though a number of his neighbours did. After faults in his own and in some of his neighbours' technology came to light, he tried to obtain a maintenance contract, but by then neither the installer nor manufacturer was interested in entering into such a contract.

Another householder had tried arranging maintenance for his technology (MVHR, PV and STHW systems) for some time. He lived in a development containing privately owned homes (including his own) and shared-ownership homes; for the latter, the housing company involved had arranged for a maintenance company to tend to the technology. The interviewee had approached this maintenance company to try and also attain an annual maintenance contract, which he had eventually secured, though the first visit offered was not for eight months and the contract excluded the PV system (which he was advised needed no maintenance). Given the efforts required to attain this contract, he considered the process should be made easier. Both of these interviewees highlighted a fifth factor that can hinder the extent to which LZC technology is maintained; maintenance contracts can be difficult to establish.

Although the householder discussed above had now obtained a maintenance contract, he was concerned about the associated on-going costs; the MVHR and STHW systems were costing £100 and £169 per year respectively. He would not have chosen to install a STHW system himself, given that its benefits were unclear and maintenance costs might offset any benefits. This householder had never solely relied on his STHW system, having always had the gas boiler on, as initially set up when he moved in. This operating mode would have adversely impacted on the benefits he could have received from the STHW system.

In the preceding paragraphs, various contributory factors that help account for why 46% of interviewees do not currently monitor or maintain their LZC technology have been identified. These include the lack of *any* documentation on their technology; the absence of maintenance information within documentation provided; householders' lack of reference to the documentation provided; a lack of proactive contact from third parties in relation to getting technologies serviced; the reinforcement of a non-maintenance stance by repair persons; and a difficulty in arranging for servicing for those that have tried. These factors do not all apply to *all* non-maintainers. What then do most have in common - they do not remember reading any information that recommends maintenance and they have not had any maintenance tasks suggested to them by other sources. A lack of maintenance of LZC technology has been noted in other studies. Both the NHBC Foundation (2012b) and Stevenson et al. (2013), for example, report that MVHR-users may not undertake any filter changes despite such maintenance being necessary for the correct functioning of the technology (McLeod, Hopfe, & Rezgui, 2012). Similarly, Munzinger et al. (2006) note a low attendance to PV systems, with only 40% of householders checking their PV display monthly. The Zero Carbon Hub (2012a) suggests that the reason householders are not undertaking basic maintenance (specifically the changing of MVHR filters) is that possibly they do not appreciate its necessity. This research has contributed to a more in-depth understanding of the factors that hinder and promote maintenance activities.

I now turn to the 14 interviewees who have some monitoring or maintenance arrangements in place. In half these cases, the responsibility for arranging this resides with a third party and, in all but one such case, the technology includes a communal system. For communal systems, this responsibility rests with the management company, or other managing organisation, and householders pay for this through a service charge. Three of the interviewees lived in a development where the provision of hot water and space heating were centrally provided through the possible use of three different technologies – a biomass boiler, a CHP system and three gas boilers. The need to annually maintain these had led to prospective high service charges; these were of significant concern to the interviewees and the subject of on-going debates:

> 'Because you see, one of the arguments in this meeting was, we're paying for the service of the CHP, the service of the biomass and the servicing of three separate gas boilers ... I mean no other household would ever do something like that.' (ID804, CHP, communal biomass & MVHR)

This development's occupants had met with the management company and challenged the annual maintenance costs initially established. Independent of the management company, certain occupants contacted other maintenance companies and attained significantly reduced quotes. These residents' discontent centred on the imposition of unreasonable maintenance costs - partly due to the management company not obtaining competitive quotes for this work and partly because there were three communal technologies to maintain, which appeared excessive.

The other three interviewees with a CHP system lived in a large block of flats where the energy services company was owned by the local authority. Here, the magnitude of the energy costs was not highlighted as being of particular concern and it was not a subject of discussion between the interviewees and other residents.

The remaining case where a third party arranged for maintenance involved a shared-ownership home. Here, the technology itself was not communal (MVHR and PV systems) but maintenance and access to it was strictly the housing company's domain - they had arranged for a maintenance company to service the technologies for at least the first year and they had also managed the rectification of faults during this time (such as caused by blocked filters in the MVHR system). The issue for the householder centred on having to be at home to allow access to the maintenance company and also to the increasing service charge levied for this and other maintenance arrangements. The interviewee did not have the opportunity or authority to self-maintain her MVHR unit, which was located behind a locked door in the attic[126]:

> 'They *[the housing company]* have partitioned off half of the room – the space where the box is – and it's locked, and they took the key.' (ID1154, MVHR & PV)

[126] An arrangement also observed by Monahan (2013) within MVHR-fitted social housing.

This householder had experienced a series of blocked filters with the MVHR system and wondered whether it would be more convenient and cheaper for her to be trained on how to change filters:

> 'I mean how much more does that cost, involving two other - well *[the housing company]* and the specialist contractor that comes out to do it, whereas if you just did it yourself it would be a lot less costly. If it was a simple job, which I think it is…' (ID1154, MVHR & PV)

So, for four of the seven interviewees where the technology's maintenance was arranged by others, a key concern was the cost thereby imposed upon them. In one development, where three of these interviewees lived, the residents had worked effectively together to contest these costs.

The remaining seven of the 14 interviewees who had some maintenance (or monitoring) arrangements in place were responsible for arranging these themselves. What factors, then, had led them to do this? In four instances, the interviewee's maintenance activities had been shaped by someone repairing or servicing their technology:

> 'So when they were fixing it the second time, they also had it in their house, they said this is how you've got to use it, just make sure the bar is at a one bar pressure, you'll be fine.' (ID155, STHW)

This householder monitored the pressure gauge every few days as the STHW system had previously leaked. He had been told by the repair company (who were also the installers) how to replenish the system's fluid, which he did on a monthly basis. This householder was unaware of the *recommended* maintenance schedule (or whether it was detailed in the instruction manual) and had no planned external service arrangement in place. To an extent, this householder monitored and self-maintained his technology, and his actions had been shaped by advice received from those undertaking repair work.

Another householder had experienced several faults with his STHW system and through conversations with repair persons had been advised to check pressure levels:

> 'If the pressure in the system goes down, which I'm supposed to look at, then you call in somebody.' (ID826, STHW)

However, once the system was working effectively in summer-time, he ceased regular checking. During summer-time, he relied on the technology and, to an extent, he therefore continued to monitor the system's status through the adequacy of hot water provision. From attending to previous faults, he now had contacts to use for future maintenance or repair purposes. To the extent that it was undertaken, this householder's monitoring activities had been shaped by advice from those repairing his technology and he had not consulted the instruction manual provided.

The other two householders had both arranged to service their technology when moving in to their homes, each of which had housed a previous occupant. The first of these sourced a 'solar hot water service engineer' through the internet, who subsequently serviced his technology and provided him with monitoring advice:

> 'He warned me about the pressure meters.' (ID240, PV & STHW)

The pressure meter was checked weekly and if the pressure was to fall, the householder was to re-contact the service engineer. His written instructions stated nothing about maintenance and he stated he would follow the service engineer's advice regarding servicing frequency:

> '… the chap I spoke to said every 2 or 3 years really is good enough.' (ID240, PV & STHW)

With regards to his PV system, he had been told 'that fundamentally you fit it and leave it', so he was not planning to maintain that. The second householder who moved into a previously-occupied home also wanted the technology serviced. She contacted the management company for her apartment block, which had the installer's contact details:

> '… I wasn't sure that mine was working properly, so I had the firm in to service it and it needed more anti-freeze in the panel. So I was glad I had had it serviced. In some ways, the cost of the servicing doesn't make it cheap but it's using modern technology and its being eco-friendly.' (ID265, STHW)

Although the instruction manual recommended annual servicing, the householder stated she would follow the service engineer's recommendation of a two-yearly service, possibly partly driven by the service's cost (£150 to £200). The engineer demonstrated how to replenish the system's fluid, but she felt insufficiently competent to do this:

> 'There's a pipe, a tube that you connect to top up something. So I'd have to have him in because that's too technical.' (ID265, STHW)

In these four cases then, householders' maintenance activities and arrangements had been shaped by advice from those repairing or servicing their technology. In the one instance where the instruction manual was known to contain recommendations on service frequency, these were overridden by a service engineer's advice.

I now consider the remaining three interviewees who undertook some monitoring or maintenance activity. A factor shaping the maintenance activities of one of these householders was his professional experience; he knew how to monitor and self-maintain his technology through experience gained as a building surveyor. He monitored the STHW system's pressure gauge from the outset and topped up fluid levels as necessary, typically yearly:

> 'It is quite complicated because it's a pressurized system – you have got to connect a flexible union onto the system to pressurize it and then you have got to open some valves to let the water through – then you have got to turn it off and disconnect it because the Water Board regulations prevent you from having a continuously connected hose.' (ID273, STHW)

Ignoring the instruction manual, he based maintenance activities on his working knowledge of such technology. Through regular pressure gauge checks, he was able to detect a significant leak from the system after a few years in the property.

There was also a singular case where an instruction manual had appeared to shape an interviewee's maintenance activities:

> '… so I just went through the manuals to try and understand what it is.' (ID958, PV & STHW)

This householder, a resident for six months, monitored the STHW system's pressure gauge and was looking to establish a service contract:

> '… we are probably going to arrange for somebody to come and do a service of the system on an annual basis ...' (ID958, PV & STHW)

His monitoring activity and the envisioned servicing arrangement appeared shaped by the instruction manual.

For the remaining interviewee, some limited monitoring guidance was initially received; it is likely that this was verbally communicated by the developer:

> 'The only maintenance that we were told was that we have essentially a bucket in the airing cupboard and we were told that if that filled up, then it was glycol leaking out of the panels and we needed to call someone.' (ID1030, STHW)

The bucket-check was made approximately yearly. This householder was not provided with a comprehensive instruction manual (just a few words regarding the control panel) and was surprised to learn through the interview that the STHW system might benefit from periodic servicing:

> 'Yes, it hadn't actually occurred to me that it might need doing; yes, we'll have to check that actually.' (ID1030, STHW)

She did not have the installer's contact details, but planned to get this from the developer. Here then, some degree of limited monitoring was undertaken, probably as advised by the developer, but no wider maintenance had been contemplated.

The frequency of maintenance by a third party appeared to be influenced, in one of the previous cases, by associated costs; here, the householder thought it had been more expensive to service her STHW system compared to a gas boiler:

> '… it was more expensive, I think it was - I can't be exactly right, but it was between £150 and £200 … They were there an hour and it was so much for the first hour. Fortunately, they finished it in the hour but the anti-freeze was over and above the charge.' (ID265, STHW)

As mentioned previously, although the instruction manual in this case recommended annual servicing, the householder was going to adopt the two-year frequency advocated by the service engineer, thus keeping costs down. Another interviewee had had to pay £200 labour costs for a repair, even though his STHW system was under warranty (as this only covered parts). He was able to avoid annual maintenance costs by monitoring and self-maintaining the technology, but he made the following point about STHW systems:

> 'I imagine it's not really worth having if you have got to have someone look at it every year and they're going to charge £100 for a call out …' (ID273, STHW)

As demonstrated by this research (Section 7.4), a proportion of STHW-users do not rely solely on their technology at any point and therefore its full capabilities and benefits are not being made apparent to them. For this cohort of users, maintenance costs may appear harder to justify as the potential benefits of undertaking such work would be less quantifiable. This situation was encapsulated well by the following quote:

> '… if the general population aren't yet focussed on the real benefits of it, they aren't going to spend money maintaining something which they don't think is going to give them the benefit in the first place.' (ID826, STHW)

Walker (2008a) draws attention to the problem such maintenance costs may present to low-income households; this research suggests, however, that maintenance costs may prove problematic (in that they are hard to justify) for the wider population if such costs are not evidently off-set by energy savings accrued through operating the LZC technology. Many interviewees would welcome forms of feedback which help them to better quantify these savings (although feedback from PV systems was deemed adequate due to the FIT) (Section 7.4).

To summarise, for half of those 14 interviewees that have some monitoring or maintenance arrangement in place, the responsibility for arranging this resides with a third party, either because the technology is communal and the responsibility of a management company or because the home has a shared-ownership arrangement, where the housing company has assumed this responsibility. For the remaining seven interviewees who have some maintenance (or related monitoring) in place, the following factors were influential: the advice received from those repairing or servicing their technology (in four cases); the knowledge gained from their professional experience; the information within an instruction manual; and verbal advice received from the developer. So, only 27% of all interviewees had personally taken on responsibility for some degree of maintenance (or related monitoring) of their LZC technology and a further 27% relied on a third party (such as a housing company or management company) to arrange for this.

The significant shaping potential of verbal advice is apparent from this research. In five out of the seven cases where interviewees undertook maintenance (or related monitoring) themselves, this was prompted by verbal advice received, mainly from those undertaking repair work on or maintenance of LZC technology. In addition, two interviewees who did not undertake maintenance also appear to have been shaped by verbal advice from repair persons[127]. In comparison, in only one case did written documentation appear to prompt maintenance activity. However, three interviewees in the non-maintainer category did state that the documentation on their technology did not stipulate any maintenance requirements; it is therefore possible that this absence of written advice reinforced a non-maintenance stance. These findings suggest that verbal advice (which may either promote maintenance or encourage a non-maintenance stance) has a significant shaping potential on users; the shaping potential for written material, where provided, is less evident. In other words, informal modes of distributed inscription as presented by verbal advice have a more evident shaping potential than formal modes of inscription (such as instruction manuals).

25 out of the 26 interviewees stated that no-one, whether it be the developer, installer or manufacturer of the technology, or any other organisation, had proactively contacted them to advise them on how best to maintain their technology; to market maintenance and repair

[127]Such factors that can both promote and hinder changes, in an energy-saving context, have been stated as having a 'double valence' in Bartiaux's (2008, p.1) writing.

services; or to assess and inform them as to whether the technology was functioning as intended[128]. For the two householders that had tried to arrange for maintenance contracts, difficulties had been experienced. These two findings highlight that there is no effective support framework in place for those that move in with LZC technology, whether it be from the local authority, developers, installers, manufacturers or others. This concurs with an NHBC Foundation study (2012b, p.8) that concluded there was inadequate 'after-sales support' for such households; similarly, in a study of 72 GSHP and ASHP-users (mainly retrofitters), 22% were dissatisfied with the technical support available (Caird, Roy, & Potter, 2012). A smaller scale study involving six households spread over four new developments established that the developer had not sought any feedback on householders' experiences with installed LZC technology (NHBC Foundation, 2013b). The finding in this research that there is no effective support framework in place for those that move in with LZC technology corroborates such previous studies.

8.3.2 How are householders & technologies shaped by maintenance processes?

In Section 8.3.1, I explored what factors influenced, or shaped, the prevalence of maintenance activities. In this section, I focus on how maintenance processes in turn shape householders and LZC technology. Turning first to householders, Section 8.3.1 highlighted a number of ways in which householders may become shaped by maintenance activities. Firstly, through monitoring the technology and arranging for or undertaking maintenance work, the user becomes more attentive to the technology and alert to changes with it. Secondly, in so far as periodic monitoring checks and maintenance activities are undertaken, new household routines are initiated. Thirdly, where householders arrange for maintenance directly, they attain a connectedness to those that provide maintenance support. There was some concern expressed regarding the on-going maintenance costs, compared to the energy costs saved through the technology's continued operation. Lastly then, through the processes of maintenance, householders may become sensitised to the uncertain viability of maintaining their technology in the longer term due to cost factors.

How then are LZC technologies shaped by maintenance processes? Firstly, the aim of maintenance activities is typically to help maintain the technology's performance. Much LZC

[128]In two instances, household energy consumption and the indoor environment were being monitored by a university research team, but no advice had yet been received from them in relation to the LZC technology.

technology will gradually deteriorate if unattended to, as evidenced by householders' accounts in this research; fluids leak out, filters get blocked and parts cease to serve their function, for example. Dependent on the extent of maintenance undertaken, it can provide a degree of protection against and warning of such deteriorations. Maintaining technology to a physical standard close to that intended by designers should help ensure it also performs as intended, in terms of the quantities of and efficiencies with which low carbon or renewable energy is generated. Thus, maintenance can impact on the physical integrity, lifetime and performance of LZC technology.

Secondly, in its contribution to sustaining or improving the technology's performance, maintenance processes also serve to protect against deteriorations in the technology's image. Where technology has been incorrectly fitted, maintenance checks by knowledgeable persons can identify this before major inconveniences result. Without such proactive checks and in the absence of observable faults, such faulty and potentially underperforming technology may continue undetected for considerable periods of time, as evidenced by this research. The likelihood of such scenarios is heightened where householders do not ever rely solely on the technology for the provision of an energy service. Both the continued operation of underperforming technology, potentially since its commissioning, and the occurrence of significant fault events have the potential to undermine users' regard for their technology. Where users' views are discussed with others, such conversations may additionally tarnish the technology's image more widely (see Section 9.3). From a public relations perspective, then, effective maintenance can provide a 'damage limitation' service to this emergent energy sector where substandard and faulty installations are common, as evidenced by this research. Thus, maintenance can impact on the image of LZC technology.

Thirdly, when organised or undertaken by householders, maintenance promotes an on-going working relationship with LZC technology, ensuring it remains (or periodically returns) to the householder's consciousness. Not surprisingly, those seven interviewees that undertook some form of maintenance (or related monitoring) all stated within their questionnaires that they were interested in the ways in which their technology worked and what affected its performance levels. The interviewees' attendance to maintenance processes contributed to the technology's visibility within the home and such processes carve out a space for these technologies in their user's routines, strengthening the technology-householder association. Thus, maintenance enhances the prominence of LZC technology within the home.

In addition to furthering connectedness with householders, maintenance processes also connect technology to maintenance contractors, unless householders undertake maintenance in-house. This enables knowledge of the technology's status to be transferred to others beyond the home, which potentially contributes to some form of feedback for installers and manufacturers, where these are involved. In this way, maintenance can add to the connectedness of technology beyond the home.

In their research on 'climate change experiments' on an urban scale, Broto & Bulkeley (2013, p.1936) view maintenance as a 'structural process'. Based on this research, however, I would argue that maintenance (certainly of household LZC technologies) should not be viewed simply through a structural lens – there are additional not-so-structural elements to be acknowledged. As previously discussed in this section, LZC technology can be shaped in various ways by maintenance processes, including improvements to their physical integrity, lifetime, performance, image, prominence and connectedness. Householders also become shaped by maintenance processes by becoming more attentive to their technology, enrolled in new household routines and potentially connected to knowledgeable others. Householders may also become sensitised to the uncertain viability of maintaining their technology in the longer term due to the associated costs.

8.4 Conclusions

In this chapter, I have considered the prevalence of both maintenance and repair activities and the various ways in which these shape householders and LZC technology. In Section 8.2.1, I established the prevalence and cause of faulty LZC technology and how these come to light. 58% of interviewees (n = 26) drew attention to faults experienced, with at least half of these moving in with faulty technology at the outset. Some promptly established installations were sub-standard, but others did not because either the fault's impact on the technology's performance was unnoticeable; adverse effects arising from the fault took time to build up to a discernible level; incorrectly configured systems operated satisfactorily for a period of time until a fault-induced event occurred; or householders did not know what to expect from their technology. The reported causes of faults encompassed the operation of technology in empty properties; damage to parts during installation; incorrect configuration of parts during installation; installation of incorrect parts; missed-out parts; deterioration in parts; escape of fluids and tampering by third parties (birds). Predominantly, householders became aware of the faults themselves, but sometimes it was neighbours who drew attention to the likelihood of there being a fault and, in a couple of instances, manufacturers proactively replaced technology that was considered to be potentially faulty.

In Section 8.2.2, I went on to consider how householders and technologies become shaped by the processes of repair. Conversations with repair persons appeared to have significant shaping potential on householders' understanding of and interactions with LZC technology, as such specialists often constituted the first opportunity householders had to discuss their technology with a knowledgeable other. Four interviewees reported an increased engagement with their technology following such conversations, ranging from improved understandings to the self-maintenance of installations. Rather than always furthering engagement with LZC technology, however, conversations with repair persons were also seen to promote a disengaged stance by householders on three occasions. Here, repair persons verbally black-boxed the technology, absolving householders of any responsibility for monitoring or maintaining it, and these conversations effectively configured the householders as passive users. The experience of dealing with faulty installations was found to shape householders' perception of their technology in divergent ways, from making them more wary of the technology to making them more comfortable. As regards the LZC technologies, these may be shaped in a number of ways by the processes of fault identification and repair, encompassing changes to their physicality, functionality, manageability, image and lifetime.

In Section 8.3.1, I established the extent to which LZC technologies were maintained and some of the underlying reasons for this. 46% of interviewees (n = 26) had never self-maintained their technology or had it proactively maintained by others. Various factors appeared to contribute to this lack of maintenance, including the lack of any documentation on their technology that could guide them; the absence of maintenance information within documentation provided; householders' lack of reference to any documentation provided; a lack of proactive contact from third parties (such as installers or manufacturers) in relation to getting technologies serviced; the reinforcement of a non-maintenance stance by repair persons; and a difficulty in arranging for servicing for those that had tried. Most non-maintainers had the following in common; they do not remember reading any information that recommends maintenance and they have not had any necessary maintenance tasks recommended to them by any other source.

54% of interviewees (n = 26) had some monitoring or maintenance arrangement in place for their LZC technology. In half these cases, the responsibility for arranging this resided with a management or housing company. For the remainder, a number of factors emerged as being responsible for shaping monitoring and maintenance activities; namely, the advice received from those repairing or servicing their technology; the knowledge gained from their professional experience; an instruction manual; and verbal advice from a developer. The research findings indicated that verbal advice (which may either promote maintenance or encourage a non-maintenance stance) has a significant shaping potential on users; the shaping potential for written material, where provided, was less evident.

Additionally in Section 8.3.1, I examined the extent to which householders received on-going communications in relation to LZC technology. 96% of interviewees (n = 26) stated that no-one (not the developer, installer, manufacturer or any other organisation) had proactively contacted them to advise them on how best to maintain their technology; to market maintenance and repair services; or to see whether the technology was functioning as intended[129]. For the two householders that had tried to establish maintenance contracts, difficulties had been experienced with doing so. These two findings highlight that there is no effective support framework in place for those that move in with LZC technology in new homes, whether it be from the local authority, developers, installers, manufacturers or others, a finding which supports previous studies.

Finally, in Section 8.3.2, I considered how householders and LZC technologies are shaped by the processes of maintenance. I found that householders become more attentive to the technology; enrolled in new household routines; connected to knowledgeable others (where external maintenance support is arranged); and, also, potentially sensitised to the uncertain viability of maintaining their technology in the longer term due to the associated costs.

LZC technology becomes shaped by maintenance processes in a number of ways. Dependent on the extent of maintenance undertaken, it can provide a degree of protection against and warning of deterioration and thereby impact on the physical integrity, lifetime and performance of the technology. It was also noted that maintenance can contribute to the prominence of the technology within the home and to its connectedness beyond the home, where maintenance contractors are employed. I commented that, from a public relations perspective, effective maintenance can provide a 'damage limitation' service to this emergent energy sector where substandard and faulty installations are common. The continued

[129]In two instances, household energy consumption and the indoor environment were being monitored by a university research team, but no advice had yet been received from them in relation to the LZC technology.

operation of underperforming technology and the occurrence of significant fault events have the potential to undermine users' regard for their technology, as may be communicated to others, thereby contributing to the wider public perception of such technology. Through the early identification of such installations, maintenance has the potential to positively impact on the image of LZC technology.

The topic of communication is explored further in the next chapter, both in terms of intra-household and inter-household conversations on LZC technology.

Chapter 9: Thinking & talking about LZC technology

9.1 Introduction

One aspect of the LZC technology-householder association that remains to be considered in this thesis is the degree to which householders talk about their technology with others. As discussed in Section 4.2, domestication encompasses the objectification of technologies through intra-household conversations. It also encompasses the extent to which householders converse about their technologies with persons outside the home; that is, the extent to which they engage in the conversion component of domestication. Although how particular householders think about their technology has emerged at various points within Chapters 6 to 8, this aspect of objectification has also yet to be examined comprehensively. Thus, in this penultimate chapter, I explore further the extent to which LZC technology is discussed by users and how it is viewed.

The chapter is sub-divided into three parts: namely, the extent of household discussions pertaining to LZC technology (Section 9.2); the ways in which householders connect with others outside the home in relation to their technology (Section 9.3); and the meanings or attributes householders ascribe to their LZC technology (Section 9.4). These three parts will be introduced and summarised separately within each relevant section.

9.2 Intra-household associations

9.2.1 Introduction

In this section on *intra*-household associations, I examine the degree to which joint householders discuss and assign responsibility for their LZC technology. Three elements to this are covered. I commence by establishing the degree to which these technologies are the subject of household conversations and find that such conversations tend to be driven by on-going matters of concern (Section 9.2.2). I proceed in Section 9.2.3 to consider whether the technology slots into existing gendered patterns of everyday life and establish that men are typically responsible for these unfamiliar installations. I then look further at household responsibilities and assess who advocates changing daily routines to capitalise on the energy produced by the technology. The first and second elements are encompassed mainly by the objectification component of domestication theory and the third is encompassed by the incorporation component. The conclusions are presented in Section 9.2.5.

Through the discussion, the following research question is addressed: *do LZC technologies slot into existing gendered patterns of everyday life (Section 9.2.3).*

9.2.2 To what degree is LZC technology the subject of household conversations?

The degree to which LZC technologies are the subject of household conversations was assessed with those interviewees who lived with another adult. In six of these 14 joint households, the technology was under discussion for various reasons. In one case, there was a heightened awareness of communal technologies (CHP and biomass heating) as these were not operating as intended and the predicted costs of doing so significantly exceeded initial expectations. Regular debates on these issues with other residents, both formally and informally, stimulated on-going internal household dialogue:

> ‘We still talk about it quite a lot.’ (ID804, CHP, communal biomass heating & MVHR)

In another case, a couple had been living for less than a year with an ASHP and were still getting to grips with how best to operate it:

> ‘the upstairs is fine but the downstairs is not quick enough to react to the changing *[external]* temperatures ….’ (ID1023, ASHP)

Here, the issue of concern was the lower level of comfort experienced on the ground floor, due to the longer response times associated with this form of heating. They were satisfied overall with the technology’s performance but, due to periods of discomfort (as temperatures adjusted as required), it was a subject of conversation. Another couple had experienced difficulties in setting up a maintenance contract for their technology – hence this had been a conversational topic.

One householder envisaged that once the negative issues pertinent to them had been resolved, discussion on the technology would diminish although interest in it would remain:

> ‘… I think once this dispute is sorted, we probably are not going to discuss it that much. I’m going to keep an eye on it all the time.’ (ID958, PV & STHW)

In another household, there were seasonal expressions of wonder at the STHW system’s performance, together with one period of discussion triggered by a fault:

> '… we talk about it in the summer, when they're working. My husband became quite obsessive about running upstairs, and checking the temperature saying: 'My God, they're working really well'… 'and when the gas bill comes, it's always: 'Wow, that really is amazing. It's costing us virtually nothing to live through the summer.' And then when they aren't working, it's definitely a topic of conversation... It was a real: 'Get on to the builders because we need them out tomorrow to re-set it so they're working again.'' (ID1030, STHW)

So, in five of these six joint households, the status of the technology as a subject of conversation appeared driven by issues of concern, rather than satisfaction, that pertained mainly to financial issues but also to comfort and maintenance issues.

In the remaining eight of the 14 joint households, there was no (or limited) discussion concerning the technology. Although possibly spoken about when moving in, the technology was no longer of daily interest:

> 'I guess for the first couple of weeks it was *[a topic of conversation]* because I moved into the flat first and then she moved in with me about a month later. So it was kind of like: 'Look at this shiny new heating system we have, it's under-floor and we have – it's partly run, I don't know by how much, by a solar heating system', and it was kind of exciting, new and a novelty. I still talk about it with people outside, you know with people I haven't bragged about it before to, but I wouldn't say we discuss it, just me and her.' (ID833, STHW)

Discussion in this group appeared curtailed by the following factors: only one adult was interested in the technology (see Section 9.2.3); there was a lack of understanding regarding the technology; or the technology appeared to be functioning well and was not a matter of concern. Having reviewed the extent to which LZC technologies are objectified through household conversations, I now turn to another element of objectification; how responsibilities for the technology are distributed amongst household members.

9.2.3 Does LZC technology slot into existing gendered patterns of everyday life?

As part of the survey, householders were asked to identify whether they or another party were responsible for operating and maintaining their LZC technology (including communal systems); 40% of the 96 respondents to this question stated that a member of their joint household was responsible for these tasks (Figure 9.1) and in the majority (70%) of these 38 cases, it was designated as the man's responsibility. A further 27% of these 38 cases stated that this responsibility was shared between couples and in only one instance was a female within a joint household identified as being responsible for these tasks.

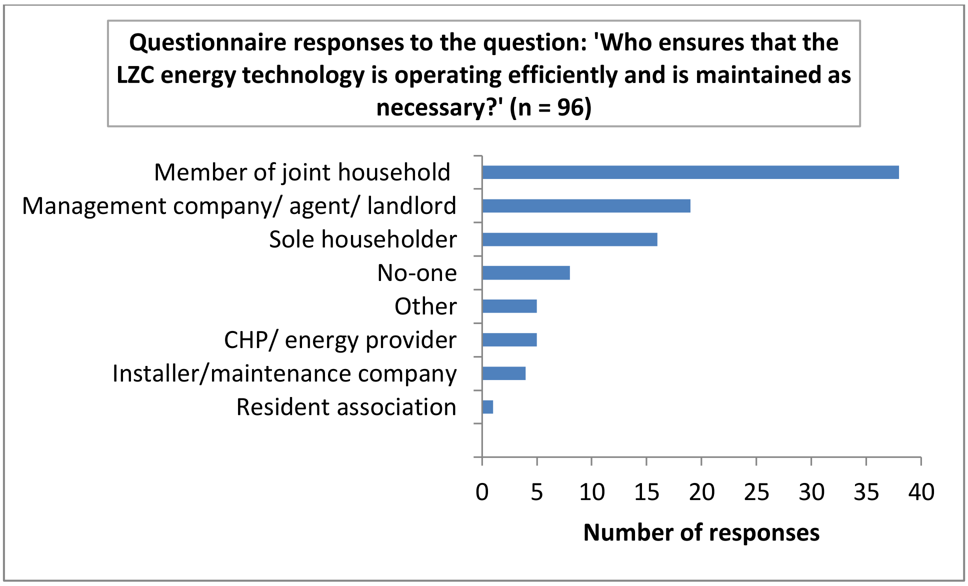

Figure 9.1. Who oversees the operation and maintenance of LZC technology?

This gendered allocation of responsibility for operating and maintaining LZC technology was further explored with those interviewees who were part of joint households. In five of these 14 relevant households, no-one paid any significant attention to these aspects of the technology. In seven out of the remaining nine joint households, the responsibility for operating, maintaining and/or repairing the technology resided mainly or solely with the man. In the two further households, this responsibility appeared more evenly shared. The predominantly male adoption of these responsibilities sat alongside a greater (self-proclaimed) male interest, ability and/or knowledge of these technologies:

> 'The rest of the family don't really understand it, so I set it up and leave it on a fairly idiot's basis that it's used.' (ID273, STHW)

> '… I think my wife in fact is a bit of a technophobe and as long as something is deemed to be working, I think she reckons that is good enough for her.' (ID240, PV & STHW)

> 'I would say I'm more interested in it than she is and I'm trying to persuade the rest of the family ...' (ID958, PV & STHW)

> '*[I'm a]* bit more knowledgeable and secondly more interested, I guess…' (ID1023, ASHP]

Even in cases where the woman partook in selecting the technology's settings, the interviews suggested that the man still considered he held overall responsibility, and men certainly appeared more active in monitoring, maintaining and/or arranging for the repair of LZC technology:

> 'She is technically minded up to a point and we went through the programming of the boiler together. She has rudimentary knowledge, if you will. If things were to go wrong, she knows how to shut it off and programme it.' (ID817, ASHP)

> '… one of the reasons we down-sized is we're both old-people and one of us is going to die at some time, not yet. So, therefore we are keeping each other informed. I've learned how to use the washing-machine; she's learned how to move money on the computer and so on. So if we need to re-set the timing on the heating, she prefers to do it and get used to the idea. She'll do anything *[that]* needs doing on it ...' (ID312, STHW)

These findings are aligned with Gram-Hanssen's (2008, p.1188) research into district heating in Denmark, where she concludes 'it is more often the norms of men or caretakers that influence the routines for regulating heating.' Similarly, Klein (1983, p.177) found that in German households with retrofitted STHW systems, these were 'usually the domain of and a challenge to the male family-head.' In research on MVHR-fitted new homes, Stevenson et al. (2013, p.79) noted that women perceive they have less control over 'ventilation when compared with men', and advocate probing this finding further. The finding in this research that men are more responsible for the maintenance and repair of LZC technology is aligned with research that has established the gendered nature of household maintenance and repair work more generally (see Barstad, 2014).

This research suggests that LZC technologies become gendered due to the division of labour prevailing within the households studied. Here, the allocation of responsibilities for the technology is aligned with, and contributes to, the existing gendered division of labour[130] and the technology is typically symbolised as a male concern. Faulkner (2001, p.83) terms such gendering processes as 'gendering by association'; that is, the gendering of the technology arises from its association with a gendered division of labour.

I now go on to explore whether any patterns can be discerned in which household member advocates the most optimal mode of use for the LZC technology. When joint households were asked (within the survey) who had the main responsibility for making sure that day-to-day practices in the home made the most of the energy generated by the technology, 58% reported that it was the man's responsibility and 42% stated that this responsibility was shared (Figure 9.2). No respondent reported that it was the woman's responsibility. The gendered portrayal of this aspect of technology-householder associations was further explored with the interviewees. Of interest, were those joint households where attempts had been made to

[130] Refer to Lagesen (2012, p.444) for an ANT informed analysis of the 'doing of gender'.

change daily routines as a result of the technology, and this was noted in six of the 14 joint households represented by the interviewees.

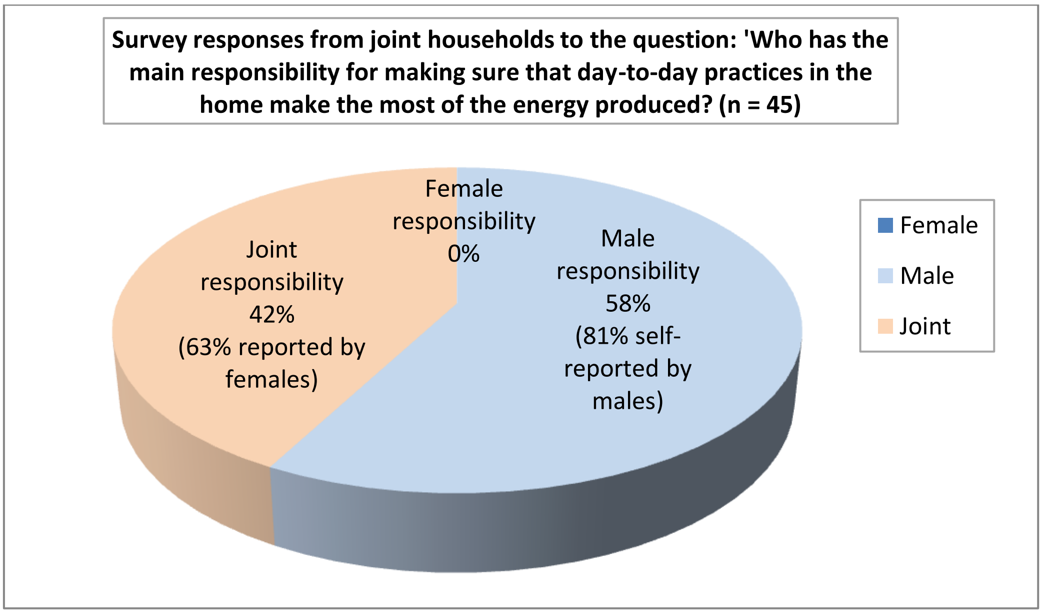

Figure 9.2. Who is responsible for ensuring that day-to-day practices capitalise on the LZC energy produced in joint households? (10 responses have been omitted from this diagram as the gender of the householder was not specified)

In two out of these six cases, male interviewees had tried to influence others to change their routines. In the following example, a man recounts how he employs gentle encouragement to successfully persuade his partner to change the timing of chores that he views as strictly residing within her gendered domain:

> 'Interviewer: In terms of encouraging appliances to go on later, is that just verbal persuasion or do you just do it yourself?
>
> Interviewee: Well the washing machine and tumble drier, those are strictly my wife's domain. I do not touch those.
>
> Interviewer: How do you encourage those to be put on later then?
>
> Interviewee: Well, I sort of skirt round it and say: 'It's a lovely sunny day, think of all that electricity we're generating, would it be better to do the washing now rather than whenever?' (ID240, PV & STHW)

In the other of these two cases, the male interviewee described the resistance that his partner exhibited to the idea of changing her bathing routine:

> '… I mean people are just going to do whatever they are going to do. I mean I did suggest to my wife when the best time would be to take a bath and she just gave me a withering look.' (ID273, STHW)

This householder likened his chance of changing his partner's routines to that of having 'as much chance with a chair'. He attributed this lack of success to the fact that his partner was not financially responsible for meeting their energy needs:

> 'They don't pay for it you see, that's the thing. It's the person who pays for it *[that]* is the person that sees the benefit.' (ID273, STHW)

This example illustrates that unwilling members of the household may restrict the degree to which load shifting can occur (a subject discussed in Section 7.4). Although the timing of routines which consumed hot water had not shifted, this household did try to rely on the technology in summer-time when the hot water generated was usually sufficient to meet their needs. If their demand outstripped the solar-heated supply, however, they relied on the immersion rather than waiting for the solar-heated supply to replenish.

In a further two of the six joint households, where attempts had been made to change daily routines, the responsibility for operating energy-intensive washing appliances during PV-electricity generating hours was shared. The remaining two of these six households were fitted with an ASHP and here both adults were involved in setting the system to adequately meet their heating needs.

To conclude, the survey findings highlight that men are more likely to have the main responsibility for making sure that daily activities make the most of the energy produced by LZC technology.

9.2.4 Gender differences in research participation rates & responses

I noted that 59% of survey respondents were men (Figure 9.3). When considering only joint households, 59% of respondents were again men. The finding that men were more likely to complete a LZC technology-related questionnaire than their female partner was corroborated by anecdotal door-step conversations: one woman stated that she would get her husband to participate as she was too busy and two others stated they would pass it on to their husbands who knew more about the technology. This gender difference in questionnaire completion has also been observed in studies on proactive installers of STHW and PV systems (Faiers, 2009), where the disparity was more pronounced (64% male participants). It has also been observed in a survey on household energy consumption, where again 64% of participants were men (Abrahamse & Steg, 2009). In contrast, research into household electrical appliances, which considered energy consumption and environmental impacts, found that 10% more females than males completed the research questionnaire (Mansouri-Azar, 1996). As advocated by Reed & Christie (2009), I have given some consideration as to whether the gender of the research participants might have influenced the research findings generated.

As illustrated in Figure 9.2, a gender difference was noted in how participants answered the question of 'who had the main responsibility for making sure that day-to-day practices in the home made the most of the energy produced by LZC technology'. The 17 women who answered this question on behalf of a joint household either stated that it was a joint responsibility (71% of the time) or the man's responsibility (29% of the time). The 28 men who answered this question on behalf of a joint household either stated that it was a joint responsibility (25% of the time) or their responsibility (75% of the time). No respondent reported that it was the woman's sole responsibility. Thus, women were more likely to say this responsibility was shared, whereas men were more likely to say this responsibility was theirs.

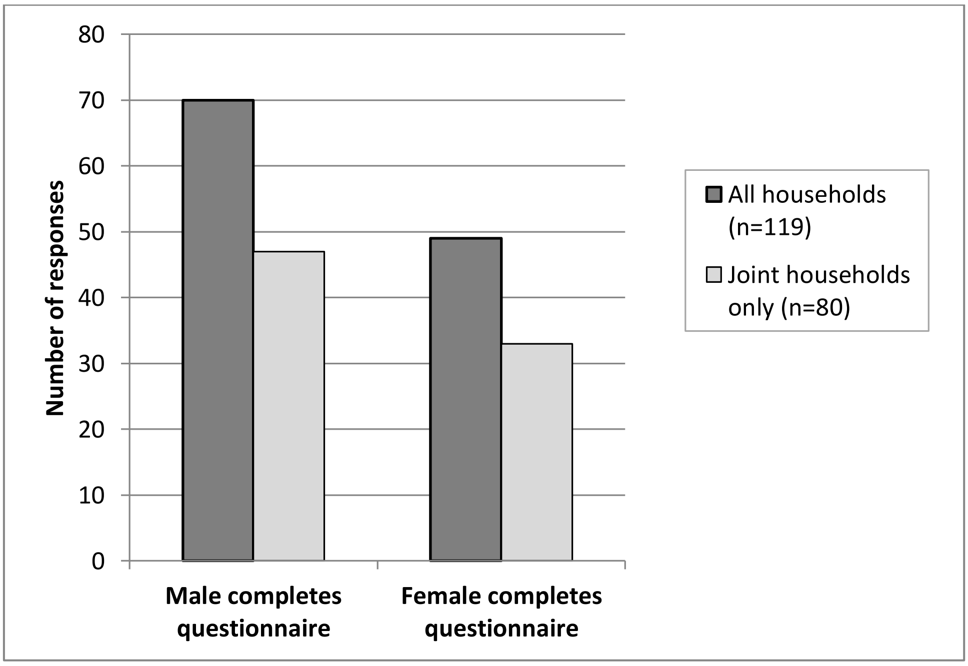

Figure 9.3. Survey participation numbers by gender and household type

This difference can be interpreted in (at least) two ways, the first one being that women and men perceive their respective contributions to making the most of energy produced by LZC technology differently. The second interpretation might be that those women who complete the questionnaire are more likely to emanate from households where these responsibilities are shared, and this is reflected in their responses. The first explanation draws attention to the possibility that the ways in which some or all of the questions are answered could be influenced by the gender of the research participant, a possibility that would also extend to the interviews conducted.[131] One way to explore such differences further would be to get each adult within the household to complete the questionnaire and to separately interview them. Such an approach might form an interesting avenue for further research into the prevalence of gendered responses within this topic.

9.2.5 Conclusions

The purpose of Section 9.2 was to examine the degree to which joint householders discuss and assign responsibility for their LZC technology. In Section 9.2.2, I explored the degree to which LZC technology was the subject of household conversations and found it was not regularly discussed in 57% of the 14 joint households represented by the interviewees. Although generally spoken about when moving in, this communication diminishes when only one adult is interested in the technology; when there is a lack of understanding regarding the technology; or, when the technology appears to be functioning well and is not a matter of concern. In the remaining 43% of joint households represented by the interviewees, the technology remains under discussion and, in all but one case, this relates to on-going matters of concern that pertain mainly to financial issues but also to comfort and maintenance issues.

I then addressed the question of whether LZC technology sloted into existing gendered patterns of everyday life (Section 9.2.3), with the generally accepted alignment of technology with predominantly male interests. I established through the survey that, where someone in a joint household was responsible for operating and maintaining the technology (n=38), this was the man in 70% of cases; in only one instance was a female identified as having sole responsibility for this, with responsibility being shared in the remainder of cases. This gendered allocation of responsibility evident from the survey was further explored with interviewees from joint households. Again, responsibility for operating, maintaining and/or repairing the technology typically resided mainly or solely with the man. To this extent, the technologies can be said to slot into the existing gendered patterns of everyday life in the households interviewed. The research highlighted a greater (self-proclaimed) male interest,

[131] Such a 'differentiated pattern of responses' has been observed in other areas of research (such as Barstad, 2014) and has been suggested as arising from one or both genders 'knowingly or unknowingly giving false impressions of the distribution of power in the areas of decision-making and responsibility' (Cloke, 2001, p. 3). Another possibility is that householders are just 'giving their impression of their intra-household dynamic processes' (Cloke, 2001, p. 3).

ability and/or knowledge of these technologies and men appeared more active in their monitoring, maintenance and repair.

I then ascertained whether any patterns could be discerned in which household member advocates the most optimal mode of use of LZC technology. I established that in 58% of joint households who answered this survey question (n=45), it was stated that the man had the main responsibility for ensuring that daily activities made the most of the energy produced, and in 42% of joint households this responsibility was shared. The gendered portrayal of this aspect of the technology-householder association was further examined during the interviews; representatives of 14 joint households were interviewed, but in only six was it evident that attempts had been made to change routines because of the technology. In two of these, the man had tried to instigate a degree of load shifting, and one was successful. In the other four households, the responsibility for making the most of the energy generated appeared more evenly shared.

Finally, in Section 9.2.4, I observed the differences in research participation rates and responses between genders. I noted that 59% of all survey respondents from joint households were men and considered whether the gender of research participants might have influenced the research findings generated. A gender difference was noted in how the question of 'who had the main responsibility for making sure that day-to-day practices in the home made the most of the energy produced by LZC technology' was answered within joint households; women were more likely to say this responsibility was shared, whereas men were more likely to say this responsibility was theirs. I proposed that this difference can be interpreted in (at least) two ways, the first being that women and men perceive their respective contributions to making the most of energy produced by LZC technology differently. The second interpretation is that those women who complete the questionnaire are more likely to emanate from households where these responsibilities are shared, and this is reflected in their responses. The first explanation draws attention to the possibility that the ways in which some or all of the questions are answered could be influenced by the gender of the research participant.

Having examined the degree to which joint householders discuss and assign responsibility for their LZC technology, I now widen the focus of study to consider the extent of users' discussions about their technology with others beyond the home.

9.3 Inter-household associations

9.3.1 Introduction

In this section on *inter*-household associations, I give attention to the conversion component of domestication. Within this study, conversion involves the ways in which householders connect with others outside the home in relation to their LZC technology (Section 4.2) and three elements to this are researched. I commence by examining the extent and nature of technology-focused interactions between households within any given development (Section 9.3.2), identifying factors that appear to promote and hinder such interactions. The role that Residents' Associations and Management Committees play in facilitating the exchange and dissemination of information is also evaluated (Section 9.3.3), and I find that they do not automatically play a role in assisting with the formation of neighbourhood norms in relation to installed LZC technology. I then widen the network under study to examine the extent of communications between householders and their acquaintances beyond the development, and whether these conversations have led to others installing similar technology (Section 9.3.4). The main findings from this section are summarised in 9.3.5. The extent and nature of technology-focused interactions between successive occupants of the same dwelling could also be viewed as falling within the conversion component of domestication, and this has previously been discussed in Section 6.5.

Through the discussion, the following three research questions are addressed: *to what extent do households in a given development provide LZC technology-related support to each other (Section 9.3.2); what role do Residents' Associations play in facilitating information exchange and assisting with formulating neighbourhood norms (Section 9.3.3); and, to what extent do new home occupants recommend their LZC technology to others and have these others proceeded to install LZC technology (Section 9.3.4).*

9.3.2 To what extent do neighbours provide support to each other?

Within this section, I examine, firstly, the extent to which residents within the same development provide LZC technology-related support to each other and, secondly, the timing and objectives of such interactions. I then provide an account of whether these interacting residents consider that the technology's presence has contributed to a sense of community within their development. Lastly, I focus on those developments where technology-oriented interactions between households are absent and explore what reasons interviewees suggest for this.

I assessed the extent of interactions between households in a given development via both the survey and interviews. 29% of survey respondents (n= 122) identified neighbours (or others with similar technology) as a source of information on how to maximise the performance and benefits from their LZC technology (Figure 7.1). Amongst the 26 interviewees, 54% had sought or received advice from other residents on how to operate, maintain and/or repair their technology, or had just discussed the technologies more generally with them.

The interview transcripts provide some insights into when and why residents turn to each other. Some did so soon after moving in to obtain guidance:

> 'I knew nothing about solar panels so I asked my other residents in the flats…Speaking to the neighbours in the flat, one with a solar panel said that they switched the boiler off. So I switched my boiler off and it worked.'(ID265, STHW)

> '… I did get to know the people who are renting the house next to me … because they came round and knocked on the door to find out what they were supposed to do with the ventilation system.' (ID424, MVHR & STHW)

Certainly in the first quote, the knowledge of how to use the STHW system effectively appears to have been successfully translated from one neighbour to another, in that it has been understood and acted upon. These LZC technologies were new to all interviewees and inter-household conversations provided an opportunity to identify commonalities or differences in each other's experiences and modes of operation; that is, they assisted with establishing technological norms as exemplified by the following quote:

> 'The only problem we've had with it *[MVHR],* particularly in damp weather, we sometimes had a smell – this is myself and my neighbour, living in No.x. The best way to describe it is you get a slightly fishy smell. It's a strange smell, but you'd only get it when it was damp …' (ID424, MVHR & STHW)

One interviewee had provided advice to others from the outset; he was the developer of his house and the adjoining two properties:

> 'Basically they were fascinated and very pleased to have them *[the ASHPs],* other than the fact that their son in the middle house continually keeps changing the thermostat and I get calls saying it's not working. It is, just *you* keep playing with the thermostat.' (ID1023, ASHP)

In a limited number of cases (see Section 9.3.3), interviewees identify their Residents' Association or Management Committee as a forum where information on LZC technologies is sometimes exchanged, although these discussions may not necessarily lead to clarification on issues:

> 'Well it has helped a bit but it has made it a bit more confusing as well because people have different ideas. So you think: 'Oh my God, have I got that right?' 'Have I got the idea right how this works?' Then you have to go back. There's a lot of information to read through, I really don't have the time.' (ID1154, MVHR & PV)

Where residents within a new development do not initially speak to each other regarding their common technology, such conversations may arise later at social gatherings:

> '… we moved in in March, and so did pretty much everybody else, and we went to a barbecue with one of our neighbours in late June of that year, and we said: 'These solar panels are amazing, we've just turned off all our hot water', and we were the only people who had. Everybody else was still using their boiler all the time and said: 'Really, do they work?'' (ID1030, STHW)

In a number of instances, technology-related exchanges and support emerges or escalates when faults in the technology become apparent. Below are two extracts exemplifying this type of interaction:

> '… quite a few people have brought them *[the developer]* back regarding the *[MVHR]* system. I know of four of us… The young girl over there brought them back because she didn't think hers was working at all and another flat – and I don't know which one it was - they were getting other people's cooking smells in their flat, and something had gone wrong with how they configured the whole thing.' (ID804, CHP, communal biomass & MVHR)

> 'People were saying: "The water, it's not as hot as it was, I had a shower in the evening, the heating's not the same, why's it different?" Nobody knew. Some people changed the heaters *[STHW panels]* and found out that's what it was.' (ID295, STHW)

Technological faults may exist from the outset but only come to light and be discussed between residents after a period of time (see Section 8.2). In one block of 19 flats, two years passed before six of the 19 STHW systems were established as being incorrectly installed. Up to this point, certain residents had complained amongst themselves that they were not seemingly gaining anything from their technology but had not taken any ameliorative action as they were unfamiliar with what to expect from it; that is, they had no performance benchmark against which they could infer the technology was faulty, as opposed to just inherently ineffective. It was only when one resident had the fault detected by a plumber looking at an unrelated issue, that the faulty systems came to light and action from the residents was catalysed:

> ‘So I said: ‘I want it looked at please’, and as it happened about three or four or more people in the flat were not getting any response from their solar system at all, they didn’t seem to be getting any value from it. One chap had the thing plumbed in reverse. Instead of being in the upstream it was in the downstream. So he had the whole thing correctly plumbed in. And then I think, largely because I’m now on the Management Committee for the flats, we thought we’d complain to the builders/developers, who brought in the experts, who then re-plumbed in, renewed and re-installed all 19 systems.’ (ID826, STHW)

Such evidence of one or more residents advising others of the need to investigate or repair their technology was noted elsewhere. In the next example, from a development where certain dwellings had STHW systems, the fault related to sub-standard insulation that was melting around one of the installation’s hot piping. The resident that discovered this fault encouraged others to have it seen to:

> ‘I had spoken to a neighbour and he had said: ‘Well, you really ought to have this done’. So I said: ‘Okay.’’ (ID312, STHW)

Offers of assistance are not always taken up, however:

> ‘… the poor lady - her husband died a few months ago and she has *no* idea about anything. She doesn’t think the solar heating has *ever* worked and I offered to go and speak to her about it but she never took me up on it.’ (ID312, STHW)

To summarise, 54% of interviewees stated that they had sought or received advice from other residents on how to operate, maintain or repair their technology, or had just discussed the technologies more generally with them. Such interactions typically involved either new occupants turning to other residents soon after moving in to gain from their experiential knowledge; neighbours exchanging information on their technology, enabling them to benchmark their own experiences and the performance of, and ways of using, unfamiliar technology; householders recommending to others that they have their technology checked for particular faults; or, technology-related exchanges and support between residents emerging or escalating when faults or other issues were found to be common to a number of installations. In such instances, residents have been seen to come together to address the issue.

Published research on the extent of associations between LZC technology-users, with which to compare these findings, is scant. Geographical research on renewable energy undertaken at the community level has focused mainly on the social acceptability of more-than-household-scale installations (Fast, 2013; Barnett, et al., 2012; Batel, Devine-Wright, & Tangeland, 2013), the factors influencing the deployment of community-owned installations (Walker, 2008b) and the dynamics of community projects (Walker, et al., 2010). The ways in which numerous household-scale installations within a community influence aspects of that community has not been noticeably researched in the UK context. One pertinent study, however, has been undertaken in Japan, where Hondo & Baba (2010, p.233) surveyed 120 active PV installers in a particular city. They reported that 33% had 'sometimes' or 'often' communicated with other PV users, a finding which is aligned with this research where 29% of 122 LZC technology-users communicated with neighbours in relation to their technology. Hondo & Baba (2010) established that those who communicated with others were, on average, more aware of their technology than those that did not. Such awareness was measured by how often the householders viewed some aspect of their installation (such as the panel or electricity generation figures). The research did not probe the conversations' content, however, but suggested it related to PV systems.

Having considered those that do converse with their neighbours about their technology, I now turn to those that do not. In the survey, 71% of respondents (n=122) did not highlight neighbours as a source of information on how to maximise the performance and benefits from their LZC technology. Amongst the interviewees, 46% had not discussed their technology with neighbours and various reasons for this were highlighted. In the presentation of these reasons, householders have been assigned to one of two categories. The first contains those that *do* talk to others within their development, but *not* about the technology. The second category contains those that do not talk to other residents much at all.

The following quotes came from householders assigned to the first category:

> 'Everyone there was quite friendly, anyway. So they had barbecues in their gardens, people would talk, but no-one specifically goes: 'Oh, solar panels on the roof – how's it working for you'… No, it didn't really happen. I'm sure a lot of them probably didn't even know they had them … Because they were mainly tenants … They just moved in with the estate agents. The estate agent couldn't tell them, so they probably never knew.' (ID295, STHW)

> 'They have conversations when other appliances go wrong – washing machines, the fridge, whatever it is. If their computer was to go off, I'm sure we'd talk about it. If nothing's wrong with it, it doesn't come up.' (ID817, ASHP)

These quotes suggest two reasons for the lack of LZC technology-related communications: firstly, that there had been no known faults with the technology and, secondly, that such conversations with renting tenants were less likely as they may be less knowledgeable about the technology, or may even be unaware of it.

This next set of quotes comes from householders assigned to the second category, that is, those who did not talk to neighbours much at all. The first comment comes from a woman living in an extra care development and she attributed the lack of interaction with other STHW-users to their advanced years:

> 'One lady is about 96, I think, the man on the other side is about 95, and there's one, two, certainly two empty flats that haven't been re-sold. And there's Dot along the end – she is very elderly…' (ID94, STHW)
>
> 'I don't see them very often, no. I might have mentioned it to them once. I don't think it's ever come up actually.' '… it's probably because it just works actually. People tend to gossip about things that don't work.' (ID155, STHW)
>
> 'It's fairly transient in some ways. *[This resident estimates more than half the flats are rented]* (ID155, STHW)
>
> 'A number of the houses are rented so the people that are renting aren't really interested in what's going on. A lot of them tend to come and go, every 6 months they've changed.' 'We don't tend to see that many people. Because we're at the front *[of the cul-de-sac],* they tend to drive past us.' (ID928, STHW) *[In a gated development of 24 houses, 25% of which were estimated as rented. All houses had roof-integrated STHW systems.]*
>
> 'At least half of them are rented so the renters are busy earning enough money to pay the rent…They're even less interested.' (ID829, STHW)
>
> 'I think because there are too many flats, most people are working, it's a bit like an isolated community. I don't see any neighbours at all.' (ID640, CHP) *[This resident attributes his lack of interaction with other residents to the large size of his block of 129 flats.]*

These quotes raise the following development-specific suggestions as to why the technology had remained undiscussed: the residents were too elderly to be engaged with; the technology worked so there was nothing to discuss – people tend to talk about things that do not work; the development had a fairly transient population due to the proportion of renting tenants, and those that rent were less likely to be interested in interacting with other residents and less likely to be interested in the technology; other residents tend to drive past rather than walk past other homes so there was less opportunity for interactions; and the large size of one apartment block was thought to discourage neighbourly interactions. The last two suggestions highlight that the circulation of experiential knowledge between neighbouring technology-users may be hindered by the development's physical characteristics, where these exclude 'spaces or possibilities to mingle and connect' (Marcus, Neumark, & Broome, 2011, p. 12).

Taken together, reasons for not discussing LZC technology with neighbours can be assigned to either the absence of known faults (technology-based) and/or the following development-based characteristics:

- composition of inhabitants (mainly the number of renting tenants but also occupants of advanced age in one case);
- predominance of driving over walking through the development;
- building design does not encourage neighbourly encounters (due to the large number of flats).

Given the numerous references interviewees made concerning renting tenants, I explored this issue further. An analysis of survey responses shows that 88% of those that turn to neighbours for technology-related information own or part-own their homes, which is higher than this category's proportion within the wider group of respondents (80%) (refer to Section 5.6, Figure 5.7). 12% of those that turn to neighbours for such information rent their homes, which is lower than this category's proportion within the wider group of respondents, which was 18% (refer to Figure 5.7). This analysis indicates that home owners (or part-owners) are slightly over-represented in the group that turn to neighbours for technology-related information, whilst renting tenants are under-represented. This suggests that owner-occupiers are more likely to turn to neighbours for support in this regard than those that rent, which supports the view expressed by a number of interviewees that renting tenants are less likely to discuss their LZC technology with neighbours.

Finally in this section, I consider the impact of LZC technologies on the sense of community within a development. The introduction of such unfamiliar technology into new developments has, as outlined previously, led 54% of interviewees and 29% of survey respondents to discuss their technology with other residents. To what degree has this technologically-driven communication fostered neighbourhood connectivity (Marcus, Neumark, & Broome, 2011) by leading to new or enhanced associations? Phrased alternatively, to what extent has LZC technology exhibited agency through influencing the extent and nature of neighbourly associations and possibly thereby enhancing a development's sense of community?

The interview transcripts provide some insights pertinent to this question. Of the 14 interviewees (54%) who had discussed their technology with other residents, six consider that the technology had led to a greater level of interaction between residents or a greater sense of community than there would otherwise have been. For these residents, the technology would have appeared to have exhibited some degree of agency in this regard:

> 'It's a key talking point.' (ID805, CHP, communal biomass & MVHR)
>
> 'I think it has added to the level of interaction.' (ID240, PV & STHW)

Five of the six residents that regarded the technology as having led to a greater level of interaction and/or a greater sense of community, live in developments where there has been significant collective grievances regarding the technology due to nuisance issues, financial concerns and/or faulty installations. Here, residents have come together to address common or communal problems rather than to celebrate common or communal technology. These five residents live in developments where the Residents' Association or Management Committee has been involved in addressing these common or communal problems.

To the extent that LZC technology has exhibited agency in promoting new and enhanced associations between residents and/or a greater sense of community, this research highlights that this agency stems, in most cases, from shared negative experiences with the technology. The role of Residents' Associations and Management Committees as drawn attention to in the last paragraph is examined further in the next section.

9.3.3 What role do Residents' Associations play in the exchange of information?

Within the published literature, the potential or existing role that Residents' Associations may play within new developments equipped with LZC technology appears not to have been researched. How communities engage with larger-scale LZC technology (such as wind-turbines) has received attention (Devine-Wright, 2009; Walker, et al., 2010) but how forms of neighbourhood governance engage with pre-fitted household-scale LZC technology remains unexplored.

In this research, the 26 interviewees represented 19 different developments, which are the unit of analysis for this particular section. Residents' Associations or Management Committees[132] were noted as operating (at varying levels of activity) within eight

[132] Where developments contain communal facilities which require maintenance (such as communal gardens, gates and lighting), Management Companies undertake this task as paid for by residents' contributions. In these situations, a Management Committee of residents may liaise between the residents and the Management Company to oversee expenditure.

developments[133]. In only three out of these eight cases have the Residents' Association or Management Committee discussed or influenced in some way the operation of the LZC technology. Each of these three developments are characterised by two factors; firstly, *all* homes are either served by communal LZC technology or *all* have individual LZC installations and, secondly, there have been financial or technical concerns with the technology installed.

One of these developments contains homes which are co-owned by the occupants and a housing company. Each home has MVHR and PV systems, so the occupants' homes have technological features and an active link to the housing company in common. The occupants had formed a Residents' Association through which they discussed technical and financial concerns relating to the technology (amongst other issues) and their aim (at the time of the interview with one of the occupants) was to draft out a common position and present this to the housing company:

> 'We've got a residents' meeting tomorrow to discuss things like this because we've been charged about £150 more maintenance fees than we were last year and it's in order to use as a sink fund for large amounts of maintenance that might be required in the future...So we're happy with that, but then one of the questions is, well, these heat recovery systems keep going wrong, who's paying for it? Is that going to come straight out of our maintenance and is that right that it should come out of there? I would have thought the warranty on these things would have been a lot longer…We don't know who to present it to - we want to present it, we want to give our thoughts to *[the housing company],* but have got to get it past *[their normal point of contact]* …' [ID1154, MVHR & PV]

In another of these developments, prior to widespread faults being detected in the individual LZC installations, the Management Committee had not discussed the technology, considering it solely the responsibility of individual residents. After the discovery of widespread faults, the Management Committee represented the residents' interests and took effective action leading to the re-installation of all 19 STHW systems. Looking to the future, one interviewee who was a member of this Committee envisaged that it would retain this engagement with the technology, keeping residents informed, for instance, of maintenance requirements:

> 'We've got to maintain the system. And what will that entail? I think it means keeping the residents informed. That is what we have to do, that and for other things as well.' (ID826, STHW)

[133] Five out of the 11 developments that lacked a Residents' Association or Management Committee were relatively small, being comprised of five dwellings or less.

So, in this case, the experience of intervening to address widespread faults with the LZC technology had effectively led the Management Committee to develop a sense of responsibility for assisting residents with their individual installations that was absent before this intervention occurred.

For five of the eight developments with a Residents' Association or Management Committee, however, the installed LZC technology had remained undiscussed, as exemplified by the following quotes:

> '… we had an AGM just a couple of weeks ago, *[the LZC technology]* wasn't spoken about' (ID265, STHW in 9 out of 14 flats)

> 'And when it *[the Residents' Association]*, does meet we're more likely to be discussing the site maintenance, the gardeners and so on, where there is management conflict. So really, the Residents' Association, to the extent that it exists, is purely to administer the management contract which we all contribute to the cost of.' (ID424, MVHR & STHW) *[Part of a large development where an unknown proportion of dwellings have LZC technology]*

These findings suggest that Residents' Associations and Management Committees, where present, do not automatically play a role in facilitating the exchange of information and assisting with the formation of neighbourhood norms in relation to installed LZC technology. In only three of the eight developments with either a Residents' Association or Management Committee, did these play a role in facilitating the exchange of information on LZC technology and in potentially contributing to the formation of neighbourhood norms in relation to how the technologies were understood, operated and/or maintained. In each of these cases, residents had technologies and concerns in common. Given that Residents' Associations and Management Committees are comprised of residents (and those renting out their properties), it is perhaps not surprising that matters of common concern feed through into the activities of these managing bodies. That is, the fact that they are *common* concerns legitimates their inclusion within the remit of the managing bodies.

So far in Section 9.3, I have researched the LZC technology-driven interactions between householders within the same development. I now widen the network of interest to look at interactions with others beyond the development.

9.3.4 To what extent do householders discuss their LZC technology with others?

69% of the 26 interviewees discussed their LZC technology with friends, the wider family or work colleagues; some of these conversations have just drawn attention to the presence of the technology but eight interviewees state they have gone further and recommended it to others and/or provided advice regarding it:

> 'I did *[discuss the LZC technology]* when I first moved in. People would talk about: 'It's a nice house' and I'd always talk to them a little bit about the sort of energy credentials, so yes, but I wouldn't now.' (ID424, MVHR & STHW)
>
> 'Yes, I've mentioned it to most people, most of my friends and family who visited, the first time I show them around, I always say we've got this new greener, environmentally friendly heating system and they say: 'What's that?', so … biomass blah blah blah…' (ID805, CHP, communal biomass & MVHR)
>
> 'I think I might have said to my friends as we discussed it, I recommend you get it.' (ID155, STHW)
>
> '… we tell everyone about it, that they are brilliant and if they are going to think about doing something green, get those because they are awesome. They definitely work.' (ID1030, STHW)
>
> 'I would actually advocate they think about it now, whereas I wouldn't have done in the past, no. Now I've had the experience of it, …, you get a certain amount of confidence in recommending it.' (ID1023, ASHP)

As the last quote indicates, as certain householders gain experience of their technology, and where they perceive that it is effective, they gain confidence in recommending it to others. Indeed, 70% of those that discuss the technology with others (n = 18) view the technology positively (for example, it provides a financial or environmental benefit, or they are proud of it).

The extent to which occupants of new homes recommend their LZC technology to others has previously not received much attention. A small-scale study of five new homes quoted certain householders as stating that they *would* recommend their technology but the number that actually *had* recommended it was unclear (NHBC Foundation, 2012d). In another study involving six households spread over four new developments, four stated they *would* recommend their LZC technology to friends, but again it was not confirmed whether anyone *had* done so (NHBC Foundation, 2013b).

The potential impact of not being able to discuss the LZC technology was evaluated via the survey. Here, householders were asked to assess whether an insufficient opportunity to discuss their technology with other users (as opposed to non-users) had constituted an obstacle to them improving the performance of their technology. As illustrated in Figure 9.4, 15% of surveyed householders viewed this obstacle as very or extremely significant.

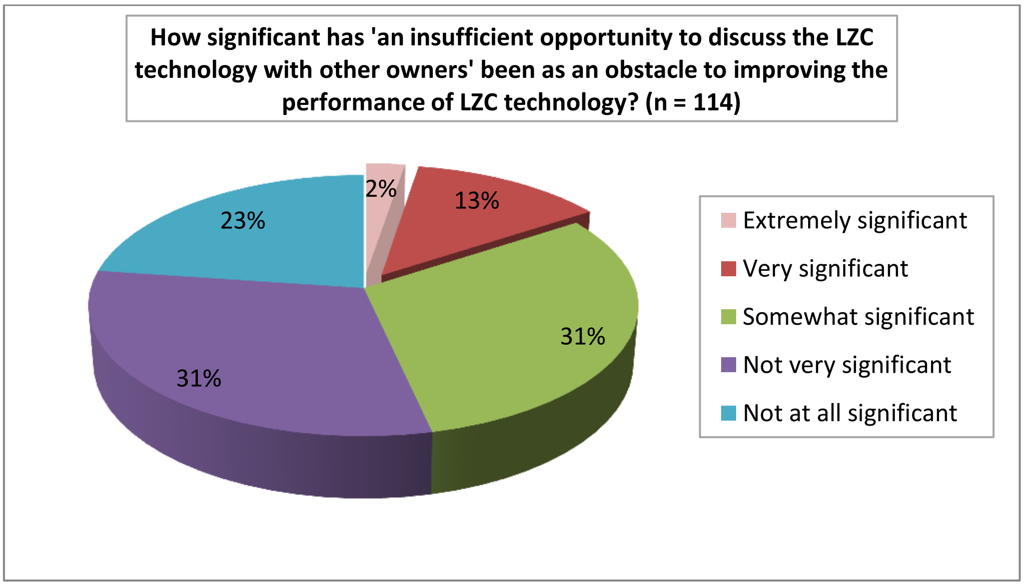

Figure 9.4. The impact of not being able to discuss the LZC technology with other users

Where the LZC technology has been discussed with friends, the wider family or work colleagues, these others are deemed in a number of instances by interviewees to be interested in the technology:

> 'When they first came round and I told them about it, one of them, when his girlfriend then came round another time said: 'Oh yes, come and have a look at this, he's got a solar panel'. There are definitely some people who are more interested I guess than others.' (ID155, STHW)

> 'I'm fairly positive about it. A number of our friends are positive as well, but some just don't want to know.' (ID240, STHW)

> 'My son was very interested in it *[the ASHP]* when I first moved in. In fact, he's seriously wondering whether he might look in to having it himself.' (ID1056, ASHP)

> '… some of them are very interested in understanding how it works' (ID958, PV & STHW)

> 'Yes, if a particular group have come over to the flat and we say we have under-floor heating and part of it is solar powered, they say: 'That's pretty cool'. I think like, if anything, it's made people possibly a bit, not jealous, but: 'You've got some of your heating coming from solar thermal panels and it's quite cool and modern and stuff'. I'm with the times.' (ID833, STHW)

In initiating discussions and eliciting interest in the workings and performance of their technology, householders are effectively projecting images of the LZC technology-user association beyond the home. In other words, their experiences become packaged up and circulated amongst acquaintances, who in turn may be influenced by them or transfer them on to others. The information that householders put into circulation will be influenced by their understanding of the technology, which may be inaccurate. For example, in the last quote, the householder believes the STHW system serves both her under-floor heating and hot water systems. Conversations with others in her apartment block, however, support the more likely scenario that the STHW system serves solely the hot water system. In such instances, householders do not act so much as 'peer-to-peer 'experience' experts' (Mlecnik, et al., 2012, p. 471) but more as peer-to-peer mis-informers.

The extent to which occupants and their circulated experiences with LZC technology have led others to install similar technology was explored within both the survey and interviews. Only 5% of those surveyed (n = 118) considered that seeing their technology had led others to install similar technology (Figure 9.5). This 5% constituted six householders, three of which had STHW systems, one an ASHP, one CHP (communal) and the other a form of communal heating (unspecified). It is considered unlikely that the last two could have promoted the installation of CHP or communal heating by others, as these are not individual technologies. However, in these instances, it might be that the respondents were indicating that their experiences have encouraged others to move into developments serviced by such communal heating systems. For the interviewees, there were no known instances where others had gone on to install the same technology as a result of their discussions. However, one interviewee was a member of a Council planning committee and he stated that, as a result of his positive experiences, he had influenced the Council's adoption of more renewable energy projects:

> 'Certainly influencing the Council in *[a particular county]* to install more photovoltaics and, as a result of some of the schemes we've approved, we have some fields of photovoltaics.' (ID826, STHW)

This research, therefore, does not provide evidence that occupants of new homes fitted with LZC technology commonly serve as effective change agents in causing acquaintances to install such technology. This finding contrasts with that from studies on active installers of LZC technology, which were found to be effective change agents for others (Wilson & Dowlatabadi, 2007). The influence of these change agents has been observed by Caird & Roy (2008, p.343), who found that 75% of 39 STHW-retrofitters stated that observing these systems in 'friends', relatives' or neighbours' homes' had been a reason for adopting the technology. It is not stated, however, whether the observed systems elsewhere were pre-fitted in new homes or adopted by active installers. The influence of such change agents may take some time to become evident, however, and many of those participating in this research were relative newcomers (72% had lived in their homes for two years or less (Section 5.6)).

Others are not always interested in discussing LZC technology; five interviewees mentioned that persons spoken to have been disinterested or cynical:

> 'If I'm talking to someone, I'll say it's very good but not enough people are particularly interested in it.' (ID273, STHW)

> '… if you say to somebody that you have evacuated tubes, they say: 'Ah, have you,' and that's it, because they have no idea what it's about.' (ID312, STHW)

> '… none of my colleagues are interested in that.' (ID817, ASHP)

> '… some of them say solar panels in this country just doesn't make sense at all.' (ID958, PV & MVHR)

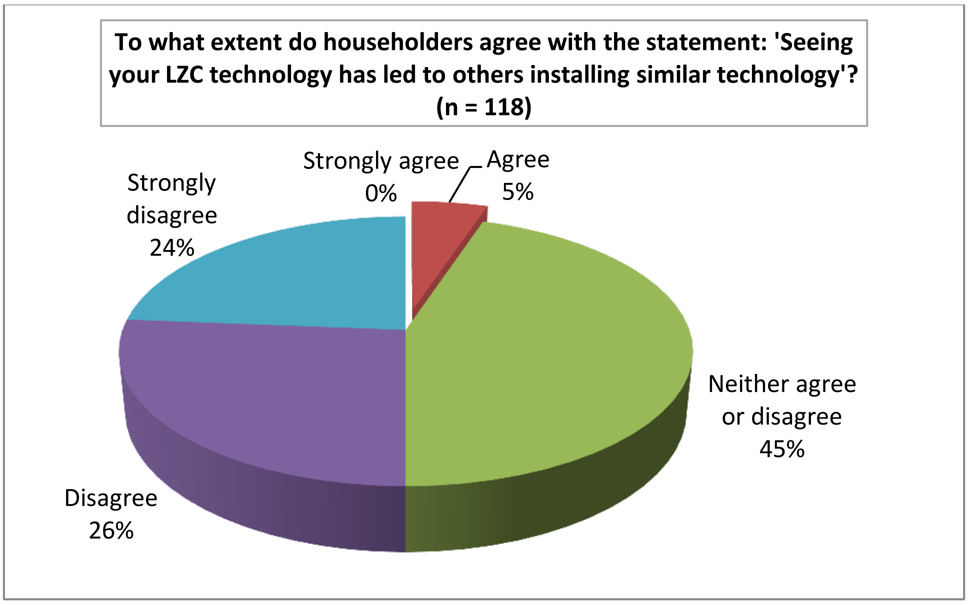

Figure 9.5. The degree to which others install LZC technology

One householder was known for his disinterest in environmental issues, so the presence of LZC technology in his new home was viewed with irony and amusement within his wider family:

> 'Well my sister thinks it's a joke, she knows my view on it… My family thought that was hysterical. When I told them we had green technology – they thought I had just gone off the planet.' (ID804, CHP, communal biomass & MVHR)

Where householders circulate their negative experiences with LZC technology, these communications may make others more wary of adopting or moving in with such systems:

> '*[Friends]* are sympathetic because they know that we are in dispute with *[the developer]* about *[the LZC technology],* they know that we feel we have been mis-sold it. And I think it's made them wary - one or two people we know may be considering buying a flat and it's made them more aware of it.' (ID786, CHP & communal biomass)

For the 31% of interviewees who have not discussed their technology much or at all with others, reasons given relate to their own disinterest in, or lack of understanding of, the technology:

> '… I don't talk about it, it's just a fact that it's been there since installation, so I had nothing to do with its installation, so it's not really of interest… Actually, to be honest, it wasn't even a consideration when I bought the place.' (ID829, STHW)

> 'My parents know we've got it. I mean they've been round. I think because the tiles are within the tiles of the roof, it's not blatantly obvious, and it's on the back of the house. So it is not something you would see or talk about… I'm sure we've mentioned that we've got it but we've not really known the benefits we've got from it.' (ID928, STHW)

So far, I have examined the degree to which LZC technology-users interact with and influence others. The research also considered whether others, beyond any given development, might have had an influence on how householders interacted with their technology.[134] In all but two instances, the interviewees did not know others (beyond their neighbours) who had any experience of their technology that they could benefit from. Two interviewees, however, did have friends or family who helped them understand their technology:

> 'I said to … my son, I said: 'I hope my hot water isn't going up there and cooling down because it's so cold outside,' and he said: 'No, it has a non-return valve, and it's only when the temperature's dropped down in the tank and the roof temperature is higher that it would go up.'' (ID94, STHW)

> 'I have a friend that works for a design company, an interior design company, who sell this kind of heat pump. So when I moved into the house, *[they explained how to]* use it properly. So that also helped.' (ID817, ASHP)

As part of the survey, householders were asked whether demonstrating success to others outside of their household had constituted an incentive for them to improve their technology's performance. As illustrated in Figure 9.6, only 4% of householders considered that demonstrating success to such others provided a very or extremely significant incentive, but a further 13% deemed it somewhat significant.

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[134] The influence of repair and maintenance persons is covered separately in Chapter 8.

The main findings from this section are summarised in Section 9.3.5.

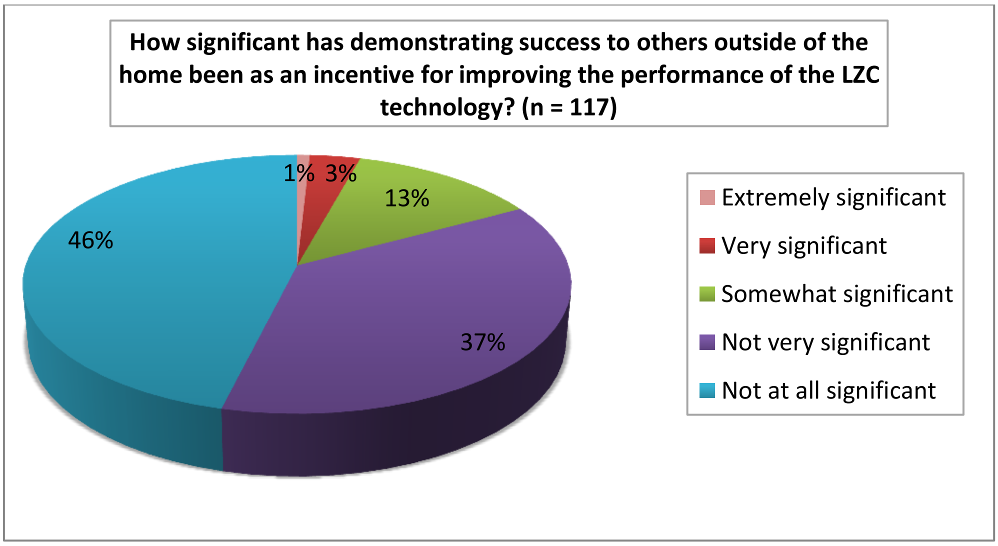

Figure 9.6. The significance of demonstrating success to others

9.3.5 Conclusions

The purpose of Section 9.3 was to examine the extent and nature of *inter*-household associations pertaining to LZC technology, which are encompassed by the conversion component of domestication. All the questions addressed relate to under-researched areas, and therefore the findings contribute to current understandings in this field.

In Section 9.3.2, I established the extent to which households in a given development provide LZC technology-related support to each other. 29% of surveyed householders (n= 122) identified neighbours as a source of information on how to maximise the performance and benefits from their technology. A larger proportion of interviewees (54%) stated that they had sought or received advice from other residents on how to operate, maintain or repair their technology, or had just discussed the technologies more generally. Such interactions, for example, occurred when newcomers turned to existing residents for assistance; when neighbours exchanged information on their experiences at social gatherings; when residents wanted to alert others to the potential for faults; and when working together to address widespread issues of concern. Interviewees who did not discuss their LZC technology with neighbours attributed this to there being no known faults with the technology or that there were a number of renting tenants, who were less likely to be interested in interacting or to be interested in the technology. Other reasons given for non-interaction related to the design of developments and the advanced age of residents, in one particular case. To the extent that LZC technology has exhibited agency in promoting new and enhanced associations between residents, or a greater sense of community, this research reveals that this agency stems, in most cases, from shared negative experiences.

In Section 9.3.3, I established the extent to which Residents' Associations and Management Committees played a role in facilitating the exchange of information and assisting with the formulation of neighbourhood norms in relation to LZC technology. The interviewees came from 19 different developments, eight of which had such an organisation, but in only three cases had the organisation played such a role. In each of these three developments, firstly, either *all* units were served by communal LZC technology or *all* had individual LZC installations and, secondly, there had been financial or technical concerns with the technology installed. In other words, residents had technologies and concerns in common. Given that Residents' Associations and Management Committees are comprised of residents (and those renting out their properties), it is perhaps not surprising that matters of common concern feed through into their activities. That is, the fact that they are *common* concerns legitimates their inclusion within the remit of the managing bodies.

In Section 9.3.4, I addressed the question of whether householders had recommended their technology to others and whether these others proceeded to install LZC technology. I established that the extent to which interviewees discussed their technology with friends, the wider family or work colleagues was curtailed by their own and others' disinterest and by their own lack of understanding. For survey participants, 15% thought that an insufficient opportunity to discuss their technology with other users (as opposed to non-users) had presented an obstacle to them improving their technology's performance.

69% of the 26 interviewees have discussed their technology with friends, the wider family or work colleagues; some of these conversations have just drawn attention to the presence of the technology but eight interviewees have recommended it to others or provided advice regarding it. As certain householders have gained experience of their technology, and where they have perceived that it is effective, they have gained confidence in recommending it. Indeed, 70% of those that have discussed the technology with others (n = 18) view the technology positively (for example, it provides a financial or environmental benefit or they are proud of it). There are also instances where householders have put into circulation their negative experiences of LZC technology, which has the potential to make others more wary of adopting or moving in with such technology. Only 5% of survey participants[135] considered that seeing their technology had led others to install similar technology. For the interviewees, there were no known instances of this occurring. However, one interviewee stated he has been able to influence a Council's adoption of more renewable energy projects.

Within this chapter, I have so far considered how householders talk about their technology, both within and beyond the home. In the remaining part of the chapter, I examine how householders view their technology.

9.4 What meanings are ascribed to LZC technology?

9.4.1 Introduction

Within the technology studies version of domestication theory (Section 4.2), the meanings assigned to technology can potentially play a part in all domestication components, from appropriation of the home through to the processes of conversion. In this final section, I explore what meanings or attributes householders ascribe to their LZC technology, both on a day-to-day level and at a more abstract, symbolic level (Section 9.4.2). I also consider whether ascribed meanings are compatible with how technologies are functionally used (Section 9.4.3). The conclusions are presented in Section 9.4.4.

Through the discussion, the following research question is addressed: *what symbolic meanings do new home occupants attach to LZC technology and do these ascribed meanings effect how the technology is used.*

9.4.2 What meanings are ascribed to LZC technology?

An indication of the day-to-day meanings or attributes assigned to LZC technology can be attained by reviewing what factors purportedly drive householders to improve their technology's performance, whether these improvements are accomplished or not. Within the survey, householders were asked to rate the significance of various factors, in terms of whether they incentivised them to improve the technology's performance; the available five-

[135] Six out of 118 survey participants

point rating scale ranged from 'not at all significant' to 'extremely significant'. The results (Figure 9.7[136]) provide an indication of what the technology means to householders.

Reducing energy costs represents the most significant incentive for improving the technology's performance, when considering surveyed households as a whole (Figure 9.7). These LZC technologies are primarily viewed, then, as vehicles through which reductions in household energy costs can be potentially achieved. At an individual level, 44% of surveyed householders rated 'reducing energy costs' as more of an incentive than 'reducing CO_2 emissions', whilst only 8% of surveyed householders rated 'reducing CO_2 emissions' as a more significant incentive than 'reducing energy costs'; the remaining 48% equated the two in terms of their significance (whether high or low).

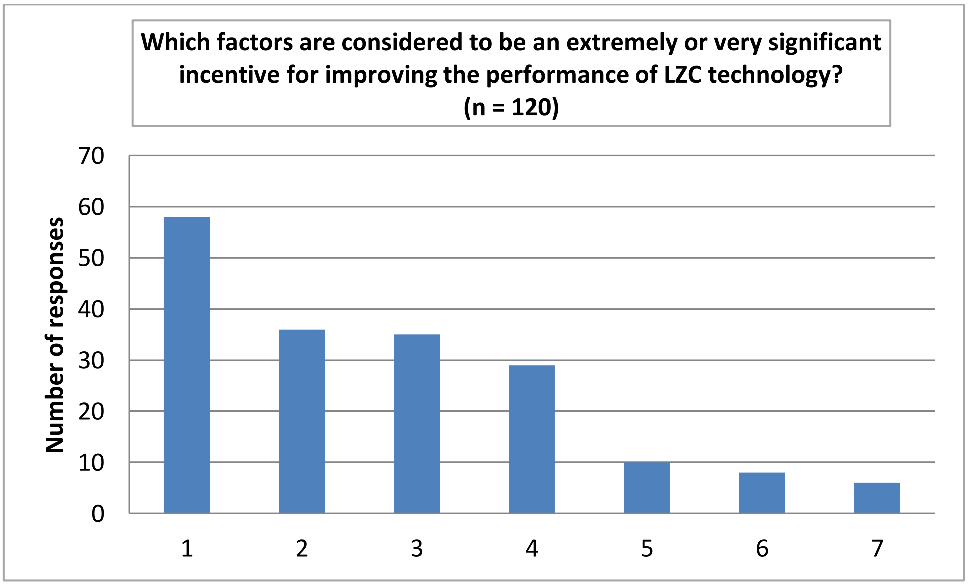

Figure 9.7. Significant incentives for improving the performance of LZC technology

Key to Figure 9.7	
1	Reducing energy costs
2	Reducing demands on non-renewable fossil fuels
3	Reducing CO_2 emissions
4	Producing more of your own energy
5	Pleasing particular household members
6	Interacting with and gaining feedback from display monitors and meters
7	Demonstrating success to others outside of the household

[136] Figure 9.7 only collates ratings marked as 'extremely significant' and 'very significant'.

This summated order of priority is aligned with results from Munzinger et al.'s (2006) research on active PV-installers, where 74% stated that the prospect of saving money was the main reason for the installation, whereas 55% stated it was for the associated environmental benefits. Additionally, in Wrapson & Devine-Wright's (2014, p.812) study on active installers of low carbon thermal technologies, the envisaged environmental benefits did not 'appear to be a principal motivating factor' in the purchase. These studies' findings contrast with those from Caird et al.'s (2008) work, where active STHW-installers rated financial and environmental drivers for their installation as relatively equal in significance. The results then from these studies on active installers of PV and STHW systems are mixed in terms of the relative significance of financial and environmental drivers for the installations.

In assessing the relative significance of the technology's financial and environmental attributes, there are fewer studies published for those who do not actively install LZC technology but move into homes pre-fitted with such devices. In one relevant study of six householders who had moved into new homes fitted with STHW systems (BRE, 2008), it was found that those who had optimised their systems and obtained the highest solar fractions were incentivised by the potential for energy cost reductions. This research then contributes to the extant knowledge in this field.

Figure 9.7 suggests that reducing demands on non-renewable fossil fuels is just slightly more significant an incentive than reducing CO_2 emissions. This finding is compatible with research undertaken on occupants of low carbon housing by the NHBC Foundation (2012b, p.6), which found that there was greater concern regarding the 'scarcity of resources, such as oil and gas, than for climate change'.

The finding that surveyed householders (as a whole) view financial incentives to improving their technology's performances as more significant than environmental incentives was also evident for the majority of interviewees:

> 'I'm quite happy with the technology because it's saving me money, but I'm not too bothered by the fact that me not burning as much fuel is going to save the planet.' (ID312, STHW)
>
> 'I'm very proud to have a functioning solar panel; I'm part of the green effort chaps. Because I think economically, it's efficient. I am using free energy and I can prove it because my electrical bills are a lot less than they should be. (ID826, STHW)

This last householder rated 'reducing energy costs' as an extremely significant incentive whilst 'reducing carbon dioxide emissions' was rated as not very significant.

For another interviewee, the presence of a STHW system was a positive influence on her decision to buy her flat. When asked whether this was because she thought it would save her money or because she considered it was an environmental plus, she stated:

> ‘We were hoping it would save us money in the long-run.’ (ID94, STHW)

For other householders, financial and environmental incentives were of equal significance (whether high or low):

> ‘It is a very green and clean technology, I think, it’s not just that it’s green in terms of you’re saving energy but that its very clean, it just sits there, it isn’t polluting anything in itself, it’s brilliant.’ (ID1030, STHW)

Interviewees were also asked directly what the LZC technology symbolised to them. The symbolisms conveyed (as detailed in Appendix 10) were mainly positive, involving projected financial and/or environmental attributes. A couple of interviewees, however, stated that they either did not know what their technology symbolised to them or that they did not really view the technology as a symbol of anything, with one describing it as: ‘Just another household appliance, in effect’ (ID295, STHW). One interviewee viewed the technology simply as an ugly building element, whilst another considered that the communal LZC technologies imposed upon their development represented a form of social engineering, to which they strongly objected, in part due to the associated operating and maintenance costs being incurred. To conclude, for the majority of interviewees, the LZC technology symbolised something positive, whether in financial and/or environmental terms. However, this viewpoint was not universal, and there were a few neutral and dissenting voices to be heard. These findings demonstrate that the meanings assigned to LZC technology are not uniform and that there is considerable ‘interpretative flexibility’ (Pinch & Bijker, 1989, p. 29) around these technologies. The research has also highlighted instances where meanings have changed as householders have come to appreciate the contribution that their LZC technology can make to meeting their energy demands (see Section 7.5.2, for example).

9.4.3 Do ascribed meanings correlate with how technologies are (mis)used?

In this section, I consider whether the meanings ascribed to LZC technologies correlate with how they are used in practise; that is, do the symbolic and functional ways in which LZC technology is domesticated correlate? I address this question through evaluating five examples.

The first householder (ID155) had a STHW system and viewed it as a symbol of progress. He was incentivised to optimise the technology's performance mainly by the possibility of reducing costs. He optimised the benefits gained by relying on the technology in summer-time and by self-maintaining and monitoring it, with the monitor for the system being accessible. This householder understood how the technology worked, as promoted by conversations with repair persons who had rectified several faults. For this first example, the ways in which the STHW installation was symbolised, understood and used were deemed *compatible* with each other.

The second householder (ID833) also had a STHW system and viewed it as a first step towards a low carbon future. She stated she was incentivised to optimise the technology's performance by the possibility of reducing energy costs and CO_2 emissions, both rated as very significant incentives for her. However, she did *not* optimise the potential benefits from the technology, as her immersion was constantly on, year-round, and the system was unmaintained and unmonitored, with the monitor for the system being inaccessibly located. She acknowledged she had a poor understanding of the technology: 'I don't know what's going on, what it's doing.' She presumed her system supplied both hot water and space heating, a scenario disputed by others interviewed in her apartment block. For this second householder, the ways in which the technology was symbolised and made use of were deemed *incompatible*. This was due, certainly in part, to a poor understanding of the technology.

The third householder (ID424) evaluated had both a STHW and MVHR system. He viewed these as part of a low carbon future and he stated that he was incentivised to optimise the technologies' performances mainly by the possibility of reducing energy costs. He did *not*, however, optimise the STHW system's potential benefits, as he never relied solely on it (following the developer's advice). With the MVHR system, he switched twice-yearly between winter and summer operating modes, but had not been advised that window opening could affect the system's efficiency. There were no monitors for the technologies and neither had been maintained over his five year occupation. For this third householder, then, the ways in which the technologies were symbolised and utilised were deemed *incompatible*; this was due to a poor understanding of the technology.

The fourth householder (ID295) had a STHW system but viewed it as just another household appliance and was only somewhat incentivised to optimise its performance, in order to reduce energy costs. He did *not*, however, optimise the technology's potential benefits, as it had never been solely relied on, was not regularly monitored and had never been maintained in four years, though had once been repaired. He acknowledged he had a poor understanding of the technology; he did not, for example, understand the monitor and was unclear as to whether the system provided hot water or electricity. His expectation of the amount of energy the system could contribute was set very low by the developer. For this fourth householder, the ways in which the technology was symbolised and made use of were quite compatible – it was viewed as just another household appliance and was not engaged with or optimised. There was a self-acknowledged, poor understanding of the technology.

The final example constituted an interviewed couple (ID804) who had moved into a development served by three communal energy systems – CHP, gas boilers and communal biomass. They also had a MVHR system installed, which they partially disabled due to unacceptably high noise levels. They were primarily interested in buying an energy efficient home with low energy costs, as promoted by the developers. However, this expectation was unmet due to high operating and maintenance costs; all three communal systems needed to be serviced annually and the developer had underestimated the associated costs and the cost of the biomass that would be required. The requirement for three communal energy systems, assumed by them to be stipulated by the local authority, was deemed excessive and an unwelcome form of social engineering. Their understanding of the energy systems was confused as different parties were providing different accounts of what was happening with the systems' commissioning and operation. For this fifth example, the way in which the technologies were symbolised as a form of unwelcome social engineering was in part a consequence of the householders' unsatisfactory experiences over which they had minimal control. These included poor, inconsistent and misleading information flows from the developer, management company and others, and higher than expected energy costs. There is therefore a degree of consistency between the symbolism conveyed and the situation as experienced by these householders.

Through these five examples, I have illustrated that the symbolic, cognitive and functional elements of the domestication process are not necessarily aligned for any particular householder, and varying degrees of disjuncture are evident (illustrative of an incomplete domestication process). So, the meanings ascribed to the technology are not necessarily realised through the ways in which the technology is operated and maintained; for example, a householder may view a LZC technology as a symbol of efficiency, but they themselves may unknowingly operate it inefficiently, due possibly to a lack of understanding (whether caused by misleading advice, a lack of information, or a lack of understandable or accessible feedback, for example) or a defective system (whose performance may be sub-optimal due to a lack of maintenance or undetected faults, as discussed in Chapter 8). Such instances where householders are unknowingly operating technologies sub-optimally may continue for prolonged periods of time, which clearly has implications for the CO_2 reductions that are going to be achieved by even those who are interested in the financial or environmental gains to be made. The finding that environmental committment alone is insufficient to yield improvements if accompanied by constraints such as inadequate information has been commented on by others such as Gram-Hanssen (2010), in the context of residential heat consumption in Denmark, and Gill et al. (2011), in the context of MVHR-users in the UK.

9.4.4 Conclusions

In Section 9.4, I explored how new home occupants view pre-installed LZC technology and what incentivises them to improve their technology's performance. These findings extended current knowledge on this subject as previous studies have mainly been restricted to smaller scale studies or have focused on active installers. Reducing energy costs represents the most significant incentive for improving the performance of LZC technology, when considering surveyed households as a whole. At an individual level, 44% of surveyed householders rated 'reducing energy costs' as more of an incentive than 'reducing CO_2 emissions', whilst only 8% of surveyed householders rated 'reducing CO_2 emissions' as a more significant incentive than 'reducing energy costs'; the remaining 48% equated the two in terms of their significance (whether high or low). For the majority of interviewees, the LZC technology symbolised something positive though there were a few neutral and dissenting voices to be heard.

By working through five examples, I illustrated that the symbolic, cognitive and functional elements to the domestication process are not necessarily aligned for any particular householder, and varying degrees of disjuncture are evident; the meanings ascribed to a technology are not necessarily realised through the ways in which it is operated and maintained.

In the last remaining chapter, I assemble the various findings from Chapters 6 to 9 to provide an account of, and explanation for, the domestication of LZC technology in new homes.

Chapter 10: Conclusions

Domestication processes: pivotal events, determining configurations & influential feedback

10.1 Introduction

This research has assisted with bringing into the public realm elements of the everyday geographies of home (Brickell, 2012) that pertain to LZC technology. Within Chapters 6 to 9, I addressed the various research questions generated by the literature review in Chapters 3 and 4. In this chapter, I draw together the research findings and generate a more integrated account of the domestication processes at play between LZC technologies and householders from a socio-technical perspective. In effect, I present a form of 'socio-technical mapping' (Rohracher, 2001, p. 144), identifying which entities are of relevance in influencing the setting under study. The research questions associated with the findings are shown in italics within the text.

The discussion is presented firstly under the headings of the four domestication components: appropriation, objectification, incorporation and conversion (Silverstone, 2006; Lie & Sørensen, 1996) (Sections 10.2 to 10.5). These components are not viewed as rigid, sequential stages of a linear process, but as overlapping, contributory processes that provide a framework for analysing and representing the ways in which householders and technologies come to interact (Section 4.2). In Section 10.6, I reflect upon some of the main research findings in order to examine their consequences and the key contributions of the research are put forward.

The planned householder support network did not materialise and Section 10.7 details how an engagement with the local authority emerged instead, who proceeded to adopt recommendations arising from the research. In Section 10.7, I crystallise out the factors that may have enabled this research to achieve relevance. Section 10.8 concludes with recommendations for action and future research.

10.2 Appropriation

I start by drawing together the findings pertinent to the appropriation of LZC technologies. These cover the degree to which LZC technologies positively influence the home selection process; the level and content of verbal advice and written information received on moving in; and the passing on of information between successive occupants.

LZC technology's influence on the home selection process

The research sought to determine the degree to which LZC technologies are actively appropriated in new dwellings. It was found that 39% of survey respondents (n=122) considered that their technology had positively contributed to their home's selection (Section 6.2). This group can therefore be considered as having actively appropriated the technology, signifying that the technologies' benefits had been envisioned and the enrolment of the technology into the householder's domestic life had begun. Here, drawing attention to the LZC technology during the sales/renting process enabled early, conscious associations with it to form; it also, I would suggest, sets it apart from other more mundane household features as something which warrants the householder's attention, thereby contributing to the objectification of the technology at an early stage.

Others (37%) were ambivalent about the agency of the technology in influencing their home's selection; for a proportion of these, the potential for this agency to manifest itself was prevented by either the absence of information on the technology or the lack of attendance to any such information received. For this proportion of householders, the technology's domestication did not have an opportunity to commence until after the property was occupied. I would suggest that not having had the technology drawn to their attention early on, could be later misinterpreted by some as signifying that the technology did not require their attention; in other words, the technology could, seemingly, be safely black-boxed.

The remaining 24% of surveyed householders did *not* consider that the LZC technology positively influenced their home's selection; that is, the technology had not been actively appropriated. For some of this group, there was no wish (or potentially ability) to be enrolled in anything but a minimal association with the technology, possibly because they were too entangled within other socio-technical networks centred within or beyond the home. Such a low level of association may adversely influence the technology's performance where this is dependent, in its operation and maintenance, on enrolling the interests of householders.

Housing industry representatives: a need for re-inscription

The research sought to determine what verbal instruction on LZC technology is provided on moving in. It was found that 42% of interviewees (n=26) did not receive any such verbal advice, whether from a housing industry representative or a previous occupant, and many of these wish that they had (Section 6.4). As previously suggested, not alluding to these technologies during conversations held could be interpreted by some as signifying that the technologies did not require their attention. The remaining 58% had received a home tour which referenced the technology and I established that these communications typically black-boxed the technology and configured the householders as passive users with a non-existent or minimal operational role. A significant proportion of these interviewees appeared initially shaped by this advice, which discouraged their enrolment (to any significant degree) into the technology's socio-technical network. Rather than instil householders with confidence in their ability to engage with LZC technology, such advice often did the opposite. A few interviewees, however, were sufficiently knowledgeable and confident to deviate early on from the non-interactive role advocated.

The research also sought to establish what householders' perceptions were of the written instructions provided for LZC technology. It was found that only 42% of surveyed householders deemed it to be sufficient (Section 6.3). Via the interviews, I further sub-divided this group (qualitatively) into three categories; the first had not consulted the information and, consequently, their views on its adequacy were not grounded in its readability or usefulness. The second category went on to describe the information as insufficient (sparsely written or complicated, for example) despite having initially stated that it was sufficient, but the third category of householder appears genuinely satisfied with the information, which has been read and has helped shape their association with the technology. 46% of surveyed householders stated that they considered the information provided to be insufficient (whether absent, incomprehensible or misrepresentative of actual arrangements, for example).

By often providing inadequate verbal advice and written information, I would argue that housing industry representatives constitute an ineffective link in the wider socio-technical network that seeks to stimulate the generation of lower carbon energy in the domestic sector. I have highlighted how housing industry representatives contribute to the configuration (Woolgar, 1991) of LZC technology-householder associations and conclude that much of their contribution does not facilitate, and may actively hinder, the effectiveness of these. In Section 3.4, I discussed how the work of 're-inscription' (Akrich & Latour, 1992, p. 262) may target entities that either *impede* the user from following the technology's prescription or could *encourage* them to do so. For housing industry representatives, the work of re-inscription could centre on ensuring that LZC technology is drawn attention to early on in the sales/renting process; that the preferred ways of using and maintaining the technology, in order to maximise its benefits, are verbally explained and visually demonstrated; and that adequate written information on the technology is effectively transferred to householders.

A loss of experiential knowledge

The research sought to establish what knowledge departing residents imparted to new users of LZC technology. The four relevant cases encountered provided an early insight on this (Section 6.5). These cases indicated that, firstly, written instructions should not be viewed as circulating entities that invariably pass between successive users and, secondly, experiential knowledge will not commonly be transferred. In the cases encountered, domestication processes recommenced from starting points where new occupants had equal or lower levels of information made available to them, compared to the previous occupants. From the technology's perspective, the users to which they sequentially become associated are likely to become less informed by the written word. However, as established within Chapters 6 to 9, it is often not written information that shapes householders' actions, but other aspects of the socio-technical network, such as the technology's configuration within the home, the availability and accessibility of meaningful feedback on technological performances, conversations held with repair persons and neighbours, and other pivotal events. The presence of these other entities (and experiences) that exhibit agency may attenuate the adverse consequences that might otherwise be expected to arise from any decline in the level of information passed on.

As established in Section 8.2, it is not uncommon for LZC technology to be faulty. When householders repair faulty technology prior to moving out, they may bequeath a less faulty installation compared to that which they first moved in with. On the other hand, nearly half of the interviewees never maintained their technology (Section 8.3) and may therefore bequeath a lower performing installation. Through this research, I have highlighted how the process of re-domestication of LZC technology will commence from a different starting point or set of socio-technical associations; for example, less information on the technology may be made available to the next occupant but the technology may have had its initial faults rectified.

10.3 Objectification

In this next section, I collate the findings pertinent to the objectification component of domestication, which cover the physical placement of LZC technology within the home; its positioning within intra-household relationships; the meanings ascribed to LZC technology; the influence of repair processes on both technologies and householders; and, lastly, the extent to which involvement in the research process may lead to a re-objectification of the technology.

Physical placement

The research sought to establish how users were configured by the design, placement and settings of LZC technology, focusing on STHW, ASHP and MVHR systems (Section 7.3). Within new homes, the technology's placement has been predetermined but may influence how the technology is domesticated (as Ghanem (2008) concluded from her research on PV systems in the UK).

I found that the typically unobtrusive placement of STHW systems (including the constituent panels, tank, pipework and monitoring devices) influenced householders' interactions in various ways. In apartment blocks and certain houses, panels were often situated out of view, limiting visual reminders of their presence. The hot water tank, pump and associated pipework were similarly placed out of view in a cupboard, sometimes behind shelves of linen (Section 7.3). Where the multiple component parts were visible within these spaces, their profusion and seeming complexity sometimes instilled confusion and worry, acting so as to deter householder interaction. Airing cupboards are a typical location for conventional hot water tanks as well as those associated with STHW systems. This constancy of location reinforced a business-as-usual approach for some, who paid no more attention to this technology than they would a conventional boiler or immersion system. I established that the visibility of the feedback monitor within the airing cupboard (its typical location) had a determining effect (together with the intelligibility of the feedback) on the frequency with which feedback was sought, which in turn influenced the potential for householders to be shaped by such feedback (Section 7.4).

STHW systems were provided in combination with conventional boilers and/or immersion systems. With respect to the settings for these combined systems, I partitioned householders into those that felt sufficiently confident to override initial settings (as pre-set possibly by the installer) and those that did not. For the latter group, a lack of understanding as to how the systems worked in combination, together with seemingly complex programmers, led to the (unquestioning) adoption of pre-selected settings. This finding emphasises the importance of installers selecting appropriate initial settings for household energy systems, as these may determine their functioning long-term. This finding supports the view that 'individuals tend to go with the flow of pre-set options' (Cabinet Office, 2011).

Similar to STHW systems, MVHR units and their associated controls were typically sited in unfrequented places, which led householders to be configured as passive users of this technology (Section 7.3). I described how this 'hands-off' design approach, whilst potentially preventing unintentional tinkering, could backfire when someone moved into a home where the technology had either not been activated by the developer or had been deactivated by the previous occupant. In such situations, MVHR systems may remain dormant long-term. In contrast, locating operating controls in an accessible location, as observed in one case, resulted in an interactive technology-user association. I observed how the 'hands-off' design approach was also ineffective in preventing the reconfiguration or deactivation of installations deemed intolerably noisy.

For STHW and MVHR systems, I established that the ways in which component parts had been positioned (in terms of accessibility) and the nature of their physical appearance (in terms of approachability, visibility and intelligibility) influenced the degree of householder interaction (which concurs with Ghanem's (2008) research on PV technology). These technologies complemented, rather than replaced, conventional energy systems and therefore householders had a choice as to whether and how they interacted with them. I concluded that a greater consideration of the installations' physical configuration and appearance is needed in order to effectively enrol householders into productive associations with these technology types.

In contrast, ASHPs replace, rather than complement, conventional energy systems. So, for householders to achieve their desired thermal comfort levels, I observed that they paid attention to how the technology was operated (that is, they needed to form an effective association with it). With regards to the technology's physical aspects, I found that the programmer was generally considered unapproachable due to its complexity or illegibility. Householders resorted instead to using the thermostat as the main control mechanism.

Intra-household responsibilities

Objectification encompasses how technology is positioned within intra-household relationships and *the research sought to establish whether LZC technologies slotted into existing gendered patterns of everyday life*. I established that there was a distinct 'gendered division of labour' (Sætnan, 1996, p. 38) relating to LZC technology. In the joint households surveyed (n=80), the technology's operation and maintenance was designated as the man's responsibility in the majority (70%) of relevant cases but otherwise (with one exception) this responsibility was shared (Section 9.2.3). The predominantly male adoption of such responsibilities was also evident with interviewees, where it appeared to slot into existing gendered patterns of everyday life. I also established that in 58% of these joint households surveyed, the man was stated as having the main responsibility for ensuring that day-to-day activities capitalised on the energy produced by the technology, with this responsibility being otherwise shared (Section 9.2.3).

The gendered portrayal of the LZC technology-householder association that emerges from this research lends weight to the assertion that, certainly in this case, 'the social relations of technology are gendered relations' (Cockburn, 1992, p. 32). Interviewed men typically saw themselves as having a greater interest, ability and/or knowledge of these technologies, and this was sometimes linked to their greater declared focus on minimising energy costs that they were responsible for paying (Section 9.2.3). These technologies were certainly new to all the interviewees and probably new for the vast majority of survey respondents. Accordingly, these technologies would have been previously untested within each household, and therefore not previously 'assigned gender characteristics' (Sætnan, 1996, p. 37). Given the observed strength of the gendered division of responsibilities, I would suggest that, on moving in, these technologies automatically slotted in with, and thus reinforced, existing 'gendered identities' (Lie, 1996, p. 205).

Ascribed meanings

The objectification of technology is also constituted by the meanings ascribed to it and *the research sought to reveal what symbolic meanings new home occupants attach to their LZC technology, and whether these ascribed meanings effect how the technology is used*. I established that these technologies are predominantly viewed as a means of reducing energy costs (as opposed to reducing CO_2 emissions, for example), which helps explain why householders become frustrated when they cannot quantify savings made (Section 7.4). For the majority of interviewees, the LZC technology symbolised something positive, whether in financial or environmental terms, although there were a few neutral or dissenting voices to be heard (Section 9.4.2). Householders' perceptions of LZC technology were open to change. For example, householders' perceptions were shaped by their experiences with faulty installations (applicable to 58% of interviewees (Section 8.2.1)) in divergent ways, from making them more wary of the technology (in terms of its on-going reliability and future repair costs) to making them more comfortable (through an improved knowledge of what could go wrong and what they should do about it)[137] (Section 8.2.2).

I illustrated through a number of examples how the symbolic, cognitive and functional elements to the domestication process were not necessarily aligned for any particular householder, with varying degrees of disjuncture evident (Section 9.4.3). Here, the meanings ascribed to the technology were not necessarily realised through the ways in which the technology was operated and maintained.

Re-objectification via the research process

The last aspect of objectification considered encompasses the placement of LZC technology 'in mental space' (Laegran, 2005, p. 82) and how this process of thinking about the technologies was stimulated by the research. The research brought the technology temporarily into the foreground for participants, and a number of interviewees made reference to the impact that this had had on their association with their technology (Section 7.5.3). The interviews provided a dedicated time in which to think and talk about the technology at length, sometimes for the first time, and this enabled the basis of routines and their consequences to be questioned. The research process also encouraged certain householders to put aside the time and effort needed to find out more about their technology. Furthermore, through relaying how other interviewees were interacting with their technology, I facilitated a form of benchmarking which enabled householders to indirectly compare their behaviour and experiences to others and to establish what might be construed as better or best practice. For some, the heightened focus on the LZC technology as promoted by this research was deemed likely to prompt a further engagement with and understanding of the technology. I would argue that the research process itself could be viewed, in these cases, as a form of intervention which enabled a re-objectification and a greater level of incorporation of the technology to take

[137] I also provided an account of how LZC technologies themselves were shaped in a number of ways by the processes of fault identification and repair, encompassing changes to their physicality, functionality, manageability, image, lifetime and reliability (Section 8.2.2).

place, as further discussed under the subject of 'trials' in Section 10.6.1. Patton (2002, p.405) attributes this shaping potential of interviews to the 'reflexive' processes that take place.

10.4 Incorporation

I now turn to the findings pertinent to the incorporation component of domestication, focusing on whether and in what ways LZC technology becomes incorporated into 'the temporal patterns of domestic life' (Silverstone, 2006, p. 235). Aspects covered include the extent to which householders seek an improved understanding of their technology; the ways in which the technology becomes incorporated into domestic life, particularly in relation to the maintenance and operating routines that emerge; engagement with feedback; and, lastly, learning from discontinuities and interventions.

Seeking a better understanding

The research sought to identify which sources of information householders refer to in order to improve their understandings of LZC technology. How the technology becomes incorporated into householders' daily lives will reflect, to a degree, their knowledge of how the technology works and how it can potentially deteriorate or fail. It was found that 61% and 35% of surveyed householders (n=122) refer to the instruction manual and some form of home user guide respectively, and other notable information sources include installers, maintenance companies, neighbours, helplines and the internet (Section 7.2). Notably, 44% of surveyed householders obtained additional information from either the technology's installer or a maintenance company. Based on discussions with interviewees and the high prevalence of faulty installations, I judge that such information is often conveyed during repair-work (Section 8.2.1). The findings demonstrate the distributed nature of the formal and informal inscriptions that guide householders' actions. 11% of surveyed householders, however, had never referred to any information source, despite half of these expressing an interest in their technology.

Modes and degrees of incorporation

The research sought to establish the degree to which LZC technology exhibits agency in everyday temporal affairs, as gauged by its incorporation into daily and periodic routines. I described the different ways in which technologies were incorporated, which involved changes to the timing of certain activities (to optimise the use of self-generated energy, for example

(Sections 7.4 and 9.2.3)); the periodic cessation of certain activities (such as when switching off conventional space heating and hot water systems (Section 7.4)); the lessening of other activities (such as minimising the opening of windows when there is a MVHR system operating (Section 7.4)); and the introduction of new routines (such as monitoring and maintaining the technology (Section 8.3.2) and engaging with informal and formal modes of feedback (Section 7.4)). I highlighted that the extent to which technology was incorporated varied markedly for certain technology types, namely STHW and MVHR systems, which complemented rather than replaced conventional energy systems. As householders have a relatively free choice as to whether and how they interact with such complementary technology, it is arguably unsurprising that a wide range of interactions (and degrees of incorporation) prevail, as evidenced by this research.

The prevailing range of LZC technology-householder associations was evident when it came to maintenance routines (Section 8.3.1). *The research sought to establish the extent to which LZC technologies are maintained and what the underlying reasons for this are*. I found that 46% of interviewees had never self-maintained their technology or had it proactively maintained by others, a situation influenced by the absence of maintenance guidance (or lack of reference to any such guidance); a lack of proactive contact from third parties, such as installers or manufacturers; the reinforcement of a non-maintenance stance by some repair persons; and a difficulty in arranging for servicing for those that had tried. The remaining 54% of interviewees had some monitoring and/or maintenance arrangements in place, but in half these cases this was arranged by a third party, such as a management company. The other seven interviewees had personally taken on responsibility for some degree of maintenance (or related monitoring) as influenced by knowledge gained from those repairing or servicing their technology (in four cases), their own professional experience, an instruction manual or the developer. I established that verbal advice has a significant shaping potential on whether householders maintain their technology, whereas the agency of written material was less evident.

Furthermore, *the research sought to identify what the wider benefits of maintenance processes are.* I showed that, through maintenance routines, householders became more attentive to the technology and alert to changes with it (Section 8.3.2). Much technology will gradually deteriorate if left to its own devices; as evidenced by householders' accounts in this research, fluids leak out, filters get blocked and parts cease to serve their function, for example. I illustrated how maintenance can impact on the physical integrity, lifetime and performance of LZC technology and how it thereby protects also against deteriorations in the technology's image, given that both the continued operation of underperforming technology and the occurrence of significant fault events may undermine users' regard for their technology. Where users' views are discussed with others outside the home, such conversations may additionally tarnish the image of the technology for others (Section 9.3). From a public relations perspective, then, I argued that effective maintenance of LZC technology can provide a 'damage limitation' service for this emergent energy sector where substandard and faulty installations are not uncommon, as evidenced by this research.

The processes of maintenance result in the technology, as well as the householder, becoming connected to those providing maintenance support (unless all maintenance is undertaken by the householder). This enables knowledge of the technology's status to be transmitted to others, potentially contributing to some form of feedback for installers and manufacturers, where these are involved. In this way, maintenance adds to the connectedness of LZC technology beyond the home, leading to its inclusion within wider networks of support.

Operating routines and engagement with feedback

The research sought to establish the extent to which feedback from LZC technology engages householders and shapes their actions (or modes of incorporation) (Section 7.4). Four technology types were researched in this context – STHW, MVHR, PV and ASHP systems.

Turning first to STHW systems, I generated a five-point typology of user (Categories I to V, Table 7.1, Section 7.4) based on the frequency of interaction with feedback and the degree to which actions were subsequently shaped. In moving from Category V to I, householders exhibited an increasing level of interaction with their STHW system, and hence an increasing level of incorporation of the technology into daily routines. In the least interactive category (containing six out of the 15 relevant interviewees), householders rarely, if ever, checked the monitor, which was viewed as inaccessible or indecipherable, and always kept the conventional hot water system on. For most in this category, there was no evidence that the technology had been incorporated to any perceptible extent into the pattern of domestic life, as far as the operation of the technology (in combination with conventional heating systems) was concerned. However, I noted that this did not preclude such householders from talking positively about the technology with friends and therefore partaking in the conversion component of domestication. I concluded that the monitor's accessibility and the feedback's intelligibility influenced the frequency with which feedback was sought, which in turn influenced the potential for householders' routines to be shaped by such feedback.

For MVHR systems, I generated a three-point typology of user (Categories I to III, Section 7.4) based on their perception of the sensory feedback experienced (thermal comfort, noise, air movements and/or air freshness), as then translated into actions or conscious inactions. Those in Category III re-configured or disconnected their installation to lessen or eradicate the noise nuisance experienced, preventing the technology's effective incorporation into domestic life.

For PV systems, I also generated a three-point typology of user (Categories I to III, Section 7.4) based on the frequency of interaction with feedback and the degree to which actions were subsequently shaped. I found that householders incorporate these technologies into their routines by regularly interacting with feedback devices, where available, and this can lead to a degree of load shifting in electricity consumption in order to increase the financial gains to be made. Flexible household routines and the availability of timers for household appliances were both seen to facilitate the ease and extent to which load shifting could occur.

For ASHPs, there was no dedicated feedback device provided (Section 7.4). I observed how householders' routines were shaped by the ASHP's more limited space heating capabilities, as caused by its inherent design and the associated lower temperature of distributed water (Section 7.3). This forced a reconfiguration of the space heating patterns previously adopted by householders, such that the heating system became constantly left on, day and night, in order to attain customary day-time thermal comfort levels. As discussed in Section 10.3, an ASHP replaces, rather than complements, conventional energy systems and thus householders need to effectively incorporate it into their routines.

I have established that the extent to which different LZC technology types are incorporated into household routines shows a noticeable degree of variation where the technology complements rather than replaces conventional heating systems. For the three complementary technologies researched in this context, the degree of incorporation was seen to be influenced by different factors. For STHW systems, the monitor's accessibility and the feedback's intelligibility were influential factors. For MVHR systems, the provision of a feedback device and unacceptable noise levels were influential factors. For PV systems, the flexibility of household routines and the incorporation of timers into the design of domestic appliances were influential. ASHPs were seen to be effectively incorporated as householders needed to operate them in a way that met their needs.

10.5 Conversion

In this section, I draw together the findings pertinent to the conversion component of domestication, which covers the extent and nature of interactions between neighbours in the same development, and with those beyond the development. Conversion as it relates to communications between successive occupants of the same dwelling has been covered under the discussion on appropriation (Section 10.2).

Interactions between neighbours

The research sought to ascertain the extent to which households in a given development provide LZC technology-related support to each other. The research found that 29% of survey respondents (n=122) identified neighbours as a source of information on how to maximise the performance of and benefits from their technology (Section 9.3). A larger proportion of interviewees (54%) stated that they had sought or received advice from other residents on how to operate, maintain or repair their technology, or had just discussed the technology more generally with them. These conversion processes were often seen to serve some purpose beyond that of general social exchanges, such as assisting newcomers in getting to grips with their technology, alerting neighbours to faults discovered with installations elsewhere in the development, and working with neighbours to get unsatisfactory situations addressed. Neighbourly exchanges were sometimes seen to constitute a *pivotal event* (Section 7.5), triggering changes in situations where residents concluded that their own technology was underperforming or that they were operating the technology sub-optimally.

Oudshoorn & Pinch (2005) contend that through the conversion component of domestication, the technology and its use within the home contributes to the shaping of relations between users and others beyond the home. Of the 14 interviewees (54%) who had discussed their technology with neighbours, six considered that this had increased interactions between residents and/or increased the sense of community (Section 9.3). Five of these six residents lived in developments where there had been significant collective grievances regarding the installed technology due to faulty installations, nuisance issues and/or financial concerns. So, to the extent that LZC technology has exhibited agency in promoting new and enhanced associations between residents or a greater sense of community, I found that this agency stems, in most cases, from shared negative experiences with the technology.

For those interviewees who had not discussed their technology with other users in their development, this was often attributed to there being no known faults with the technology or that there were a number of renting tenants, who were less likely to be interested in interacting or to be interested in the technology. Other reasons given for non-interaction related to the design of the development and the advanced age of residents, in one particular case.

The research sought to determine the role that Residents' Associations play in facilitating information exchange and assisting with formulating neighbourhood norms, and found that they do not typically play such a role (Section 9.3.3). In only three of the eight developments that featured such an organisation, did it facilitate the exchange of information on installed technologies and thereby, potentially, contribute to the formation of neighbourhood norms pertaining to how these technologies were understood, operated and maintained. In each of these three developments, either *all* dwellings were served by communal LZC technologies or *all* had individual installations[138] and, additionally, there had been financial or technical concerns with the technologies installed. In other words, residents in these developments had technologies and concerns in common.

Interactions between friends, the wider family and work colleagues

The airing (or circulation) of personal meanings and experiences attached to specific technologies contributes to the on-going development of the perceptions and understandings that associated others come to have of these technologies (Hynes & Rommes, 2006). This may then influence the course of domestication processes followed by these others if they are or become users of the technology in question.

The research sought to establish the extent to which new home occupants recommended their LZC technology to others and whether these others then proceeded to install technology. It was found that 69% of the 26 interviewees had discussed their technology with friends, the wider family or work colleagues; some of these conversations had just drawn attention to the presence of the technology but eight interviewees stated they had gone further and recommended it to others or provided advice regarding it. As certain householders gained experience of their technology, and where they perceived that it was effective, they gained confidence in recommending it to others. Indeed, 70% of those interviewees that discussed

[138] In certain developments, only a proportion of homes had been fitted with LZC technology (Section 5.6).

their technology with others[139] viewed the technology positively. In terms of the impact of such conversations, only rarely did survey participants consider these had led others to install similar technology[140] and for the interviewees, there were no known instances of this occurring. There were also cases where householders had put into circulation their negative experiences, which had the potential to make others more wary of adopting or moving in with any such technology.

What then of the 31% of interviewees who had not discussed their LZC technology with friends, the wider family or work colleagues? Here, engagement with the conversion component of domestication was found to be restricted, in part, by others' disinterest and, in part, by the householders' own view and understanding of the technology. Without some form of conversion, the processes of appropriation, objectification and incorporation and their outcomes remain hidden within the confines of the home. For this 31% of interviewees, then, the domestication processes relating to the LZC technology had had no 'public consequence' (Silverstone, Hirsch, & Morley, 1992, p. 26) and had not contributed to the potential development of future domestication trajectories elsewhere.

10.6 Further reflections

10.6.1 Learning opportunities for householders: discontinuities, interventions & conversations

The research sought to reveal what trials (experiences, interactions or receipt of new knowledge) trigger householders to shift and re-stabilise their socio-technical relations as part of the on-going domestication process. At various points within this thesis, I have drawn attention to certain non-routine happenings (interventions), disruptions to household routines (discontinuities) and conversations that throw light on the LZC technology for the householder. I introduced the term *pivotal event* to describe instances where such moments caused a longer-term shift in the degree of incorporation and, potentially, a re-objectification of the technology, highlighting how 'the everyday is formed in and through a series of events that are always potentially otherwise' (Binnie, et al., 2007, p. 517). The interventions, discontinuities and conversations that emerged from the research as sometimes representing *pivotal events* included: shutting down and reopening the home around holidays; tending to faulty

[139] 14 out of 18 interviewees
[140] Six out of 118 survey participants

installations; neighbourly conversations and participating in the research process. The agency of these *pivotal events* illustrates, as highlighted by Binnie et al. (2007, p.517), the potentiality of 'banal' events.

The potential impact that participating in the research might have on householders' association with their technology was discussed in Section 10.3. The interviews (a form of intervention (Patton, 2002)) provided an opportunity to discuss and question existing routines and their consequences, and also to convey information derived from other technology-householder associations encountered in the research. For some householders, whose domestication of the technology had either been minimal or had become stagnated in a non-optimum state, their participation in the research was thought likely to lead to greater degrees of interaction with the technology (Section 7.5.3). A few interviewees, for example, thought that they would try relying on their STHW system for the first time, once the weather got warmer. They had not contemplated trialling the technology's capabilities previously but were now planning to – the research had thus triggered them to plan a delayed trial.

The process of shutting down and reopening the home around holidays constitutes a temporary discontinuity in normal routines. By forgetting to reactivate conventional hot water systems on returning from holiday, two interviewees (representing different households) became reliant on their STHW system for the first time, without initially appreciating this (Section 7.5.2). This enabled the technology to demonstrate its capabilities and this changed the householders' expectations of it (an illustration of re-objectification). This, in turn, altered these householders' routines, whereby the conventional hot water system was thereafter switched off when deemed feasible. In relationship terms, the technology-householder association evolved from a relatively disengaged state to a more dynamic engaged one, where the technology became more fully incorporated into household routines. These two householders had initially underestimated the technology's potential contribution to meeting hot water requirements and they had never contemplated trialling it in this regard. The temporary discontinuity in routines brought about by holiday arrangements enabled, in effect, a delayed, unintentional trial to ensue.

As discussed previously, when householders become aware of faulty LZC technology (through leaks, unusual noises, deteriorating performances or neighbourly conversations, for example), the subsequent processes of repair can lead to longer-term changes in how technologies are incorporated into domestic life. For a number of interviewees, the presence of repair persons in their homes enabled them to discuss their technology with a knowledgeable other for the first time, which engendered an increased engagement with it through enhanced monitoring and maintenance activities and improved levels of understanding (Section 8.2.2). In these cases, attending to faulty installations led to influential conversations with repair persons, which could be considered as pivotal events. Conversations with repair specialists did not always promote further engagement with LZC technology, however; they were reported, on occasion, as promoting instead a disengaged stance.

In this section, I have elaborated on Lehtonen's (2003) concept of trials and introduced the notion of *delayed trials*, both intentional and unintentional. I have also introduced the concept of *pivotal events* to capture how shifts occur in the objectification of LZC technologies and in their incorporation into household routines. Delayed trials (through which the technology demonstrates its capabilities) and other pivotal events (that introduce knowledge through new or existing connections) are seen to trigger longer-term changes within technology-househoulder associations. Thus, I would argue that the domestication of LZC technology should currently be viewed very much as an on-going process open to influence and change, comprised of periods of stability; moments of change arising from pivotal events; and then re-stabilisation. In socio-technical terms, through discontinuities, interventions and influential conversations, new or altered associations are formed within the socio-technical network (such as with repair persons, neighbours or a more evidently capable technology) which have the potential to shift LZC technology-householder associations along the spectrum of domestication.

10.6.2 Reflections on the wider socio-technical network

The technology studies version of domestication theory expressly extends domestication processes beyond the home to consider the extent to which there is an institutional framework to 'support and regulate' the technology's use (Sørensen, 2006, p. 47). In this thesis, I have demonstrated that there are various aspects of the wider socio-technical network (Section 3.2.2) that influence the development of LZC technology-householder associations. These involve housing industry representatives who liaise with prospective occupants of new homes; those involved in positioning and installing LZC technology; and the institutional framework available to support the technology's operation, maintenance and repair. These aspects are considered in turn.

I have highlighted that, in a significant proportion of cases, housing industry representatives (involved in the sales/renting process) constituted an ineffective link in the wider socio-technical network created to stimulate lower carbon energy generation, for a number of reasons. Firstly, these representatives did not always draw attention to the LZC technology during the marketing and sales/renting process, which could be later misconstrued by some householders as signifying that the technology did not require their attention (Section 6.2). Secondly, where these representatives did mention the technology, they often black-boxed it and configured the householders as passive users with a non-existent or minimal role (Section 6.4); this discouraged certain householders from becoming enrolled (to any significant degree) in the technology's operation and maintenance. Thirdly, in a proportion of instances, the representatives did not effectively transfer adequate written information from the technology's manufacturer or installer onto the householder (Section 6.3). A large proportion of householders wanted more or better information and advice than they had received, not just on how the technology worked but on how to operate it (potentially alongside conventional energy systems) to maximise the benefits gained.

I would also argue that those involved in positioning and installing LZC technology often constituted ineffective links in the wider socio-technical network. Firstly, as regards positioning, the ways in which the technology and its associated devices were embedded in the home sometimes hindered householders' interactions with it. For STHW and MVHR systems, for example, the ways in which the component parts had been positioned (accessibility) and/or the nature of their physical appearance (approachability, visibility) influenced the degree to which householders interacted with these technologies (Section 7.3). For STHW systems, for example, the visibility of the feedback monitor was found to have a determining effect (together with the intelligibility of the feedback) on the frequency with which feedback was sought, which in turn influenced the potential for householders to be shaped by such feedback (Section 7.4). For technologies such as STHW and MVHR systems, which complement rather than replace conventional energy systems, householders have a choice as to whether and how they interact with the technology. Therefore, a greater consideration needs to be given to both the technology's positioning and the provision of intelligible feedback on its performance in order to effectively enrol householders into productive associations.

Secondly, as regards the integrity of the installations, *the research sought to ascertain the prevalence and cause of faulty technology and how these faulty installations came to light*

(Section 8.2.1). 58% of interviewees (n = 26) drew attention to faults experienced, with at least half of these moving in with faulty technology at the outset. Some promptly established installations were sub-standard, but others did not. The faults were attributed to causes such as the damage of parts during installation, the incorrect configuration of parts, the installation of incorrect parts and omitted parts. Predominantly, householders became aware of the faults themselves, but sometimes it was neighbours who drew attention to the likelihood of there being a fault and, in a couple of instances, manufacturers proactively replaced technology that was considered to be potentially faulty.

The research sought to ascertain whether any on-going communication had been received by householders, or any feedback sought, in relation to the LZC technology. The research found that it was rare for householders to be proactively contacted by anyone in relation to their technology (Section 8.3.2). Generally absent from the wider socio-technical network were organisations that were proactively contacting and advising householders on how best to operate and maintain their technology; marketing maintenance and repair services; or seeking to establish whether the technology was functioning as intended[141,142]. In the small number of cases where interviewees were seeking to set up maintenance contracts, they experienced difficulty in finding interested organisations (Section 8.3.2). These findings highlight that there is an inadequate support framework in place for those that move in with LZC technology in new homes (whether it be from developers, installers, manufacturers, the local authority, Residents' Associations or any other organisation) and there is scope for facilitating the domestication of LZC technologies further (through the work of 'codomesticating mediators' working at the practical, symbolic and cognitive levels (Berker, 2011, p. 266)). The lack of interaction between relevant organisations and householders and their technologies suggests a lack of reflexive governance (see Shove & Walker, 2010) at the local level. In summary, the institutional framework available to support householders in operating, maintaining and repairing their LZC technology is still, I would argue, at an embryonic stage.

Back in 2007, Boardman (2007b, p.34) argued for the adoption of the Merton Rule, stating it would help 'increase local authority involvement in and responsibility for the carbon emissions from their area.' On the basis of this research, I would argue that any such involvement by the

[141]In two instances, household energy consumption and the indoor environment were being monitored by a university research team, but no advice had yet been received from them in relation to the LZC technology.
[142] In a couple of instances, an ASHP manufacturer had proactively replaced units that had been found to be faulty elsewhere.

relevant local authority has been restricted to ensuring proposed developments comply with the policy at the planning application stage. There is much more that could be done, as evidenced by this research, to promote the effective installation and domestication of these technologies.

Through employing the technology studies version of domestication theory, this research has generated a description and, through this, an explanation of the state of LZC technology-householder relations within the selected population. As described, the situation is a complex one with many shaping determinants (such as technological configurations, the processes of repair, interactions with feedback, levels of understanding, influential conversations and other pivotal events) and a range of outcomes, in terms of the nature of ensuing technology-householder associations. What, then, do these differences in associations amount to? What are their 'consequences from a normative perspective oriented toward change'? (Bakardjieva, 2006, p. 71). One conclusion I draw is that the range of interactions observed between householders and their technologies, together with the high prevalence of faulty installations, signifies that the change envisaged and driven by policy-makers is only partially underway. In other words, the potential quantity of lower carbon energy that these technologies could be delivering (if the quality of the installation was faultless and the technology was operated[143] and maintained so as to optimise its performance) has yet to be realised in many cases. Given the current set of circumstances, then, I would maintain that domestic LZC technology should not (collectively) be considered as immutable mobiles suitable for the long-distance control of CO_2 reductions.

This research has illustrated how the use of the technology studies version of domestication theory can provide a useful framework for studying the ways in which the socio-technical relations between householders, LZC technology and other relevant entities come to be shaped. Following this approach has enabled insightful research results to be attained that have contributed to the existing knowledge-base in this emergent subject area.

10.6.3 Key contributions

Given the 'technological and social complexity' associated with the introduction of LZC technology at all scales, Walker & Cass (2007, p.467) have called for 'a more differentiated socio-technical analysis' of this emergent sector. This research has provided such an analysis

[143] In combination with conventional energy systems, where appropriate.

for new homes pre-fitted with LZC technology. The main research findings have been discussed in Sections 10.2 to 10.6. In terms of contributing to current knowledge, I consider that the following are of particular note:

- An improved appreciation of the degree to which LZC-technology in new homes is actively appropriated by householders during the sales/renting process;
- A deeper understanding of how the (in)actions of housing industry representatives may not facilitate, and may actively hinder, the development of effective LZC technology-householder associations;
- An early insight into the degree to which information on LZC technology transfers between successive occupants;
- A broader understanding (covering several technology types) of how the ways in which LZC technology is physically embedded influences the extent and nature of householders' interactions with it;
- A substantive contribution in revealing the gendered nature of LZC technology-householder associations;
- A more nuanced understanding of the ways in which the processes of maintenance and repair shape both householders and LZC technology;
- A more analytical evaluation of householders' engagement with sensory and formal forms of feedback from LZC technology;
- A substantive contribution in, firstly, describing the extent and nature of interactions between LZC technology-users within developments and, secondly, identifying the degree of involvement of Residents' Associations and Management Committees in LZC technology-related matters;
- The finding that the domestication of LZC technology should currently be viewed as an on-going process open to influence and change, comprised of periods of stability and changes arising from pivotal events (characterised by discontinuities, interventions and influential conversations);
- An improved evidence base to support the view that the institutional framework available to support householders in operating, maintaining and repairing LZC technology is still at an embryonic stage.

In addition to these contributions to current knowledge, the research's contribution, relevance and impact has already been demonstrated in two ways. Firstly, as outlined in Section 10.7.1, recommendations arising from early research findings were promptly approved for adoption by the local planning authority. Secondly, a research paper evaluating how the research came to have relevance for the local authority has been published in *Area*, one of the key academic journals within the geography discipline (Appendix 20).

10.7 Policy impact of the research

10.7.1 Engagement with the local authority

As discussed in Section 5.4.3, the attempt to initiate a PAR project foundered. Instead, as detailed in this section, an alternative research trajectory emerged during the research's third stage.

Alongside arrangements for the householder exhibition, an additional exhibition was arranged in May 2012 for WBC, developers, architects, technology installers and interest groups. This exhibition was part of the planned engagement process with WBC and was also viewed as an opportunity to disseminate early results to other organisations, thereby extending the learning process.

Details of potentially interested organisations had been amassed throughout the research and 242 organisations were invited to attend (refer to Appendix 17 for the invitation and Appendix 18 for the exhibited material). The Policy Planning Officer secured a Council meeting room for the exhibition. Via this arrangement, others (both internal and external to WBC) would possibly have perceived that WBC endorsed the research and I considered this an advantage when trying to gain the interest of others. The timing and location of the exhibition were also selected to enable WBC employees to easily attend during their lunch break.

24 individuals attended the exhibition, representing different WBC departments (corporate strategy, policy planning and development control), other local authorities, developers, installers, an energy services company and a low carbon community group. I had numerous conversations with attendees in which we reflected upon the causes and consequences of the initial findings, but two turned out to be pivotal in triggering a changed research trajectory. The first conversation was with a member of the development control team, who was concerned about the issues raised, such as the lack of maintenance being undertaken on LZC technology (Section 8.3) and the inadequate level of information handed over to householders (Sections 6.3 and 6.4). He asked what my top five recommendations for action would be for WBC. During a separate conversation, the chairperson of WBC's Climate Change Committee

Strategy group invited me to present the initial research findings at their next meeting, which opened up the opportunity to participate with key Council departments in reflecting more formally upon the findings. Given that I was allotted only a nominal 15 minute slot at this meeting, I felt there would be insufficient time to adequately present the findings. Instead, I decided to circulate upfront an electronic copy of all the exhibition posters and my recommendations for action (Table 10.1) to each committee member. I then concentrated during the meeting on discussing these recommendations.

The meeting went well and, after an hour of discussion, the Committee decided to adopt the recommendations, which needed some working through in order to map out the Council actions required. Although we had covered much of relevance, I was aware that the Committee was not in full possession of all the knowledge so far gained from the research and I wanted to ensure this was made available to them in their deliberations. I was subsequently involved with different groups of WBC staff (as arranged by WBC) in developing action plans[144].

One tangible outcome from my recommendations for action concerns the formulation of best practice guidance for the installation of LZC energy technologies in assisted living developments (as advocated under Item 2 in Table 10.1). I recommended that within such developments, LZC technologies should (i) serve only communal areas, and/or (ii) that the technologies be the responsibility of the management to operate and maintain, or (iii) that suitable support be provided to senior residents in relation to the technology. WBC have adopted this recommendation and incorporated it into their Climate Change Supplementary Planning Document (WBC, 2013b) (refer to Table 10.2).

The change in the research trajectory, where involvement with WBC emerged, illustrates the research's fluid nature in its third stage. In applying pressure for change, a researcher may need to follow paths of lesser resistance (engaging with those that are more receptive), in order to facilitate some tangible form of change in the time frame bounding a research project. The interventionist (Zuiderent-Jerak & Jensen, 2007) mode of engagement with WBC led to some tangible form of change, though this could not be viewed as a form of action research. In the interaction with WBC, setting the time frame for instigating action that could then be evaluated and refined was beyond my influence and extended beyond the finite time available for the research.

[144] This form of engagement is in line with what Summerfield & Lowe (2012, p.399) term a 'research translation', where findings are interpreted for the benefit of policy-makers.

Table 10.1: Formulating ideas for improvement & intervention based on householders' experiential knowledge and a local authority perspective		
Selected findings	**Issues/consequences**	**Ideas for improvement & intervention**
1 Incomplete installation/commissioning of LZC energy technologies		
There are developments where the LZC energy technologies detailed in developers' promotional literature (and contained within planning applications) have not been installed or, if installed, have not been commissioned.	- Potential for householders' expectations not to be met (39% of householders surveyed stated that the LZC energy technology was a positive influence on them selecting their home). - Developers are mis-selling properties. - Developers are in breach of a planning condition, and potentially the Building Regulations.	a) Could planning enforcement officers and building control inspectors incorporate LZC energy technologies more fully into their inspection and enforcement regimes, both during construction and after completion (e.g. evidence for commissioning of technologies prior to occupation)?
2 Varying approaches to assisted living developments		
Two assisted living developments illustrate contrasting approaches: ***Case 1*** – LZC energy technologies serve communal and service areas only (such as the kitchen and offices). The operation and maintenance of the technologies is the responsibility of the management, not the residents. ***Case 2*** – LZC energy technologies serve both communal areas and individual flats. For the latter, senior residents are wholly responsible for the operation and maintenance of solar thermal systems, with little support from the management.	Expecting senior occupants in assisted living developments to effectively operate and maintain unfamiliar LZC energy technologies, without direct assistance, is a questionable practice in terms of: - achieving the low carbon/renewable energy generation targets as set; and - having the potential to cause unnecessary stress to the residents in these developments.	b) Formulate best practice guidance for the installation of LZC energy technologies in assisted living developments. e.g. require that the technologies serve **only** communal areas and/or that the technologies are the **responsibility of the management** to operate & maintain or that **suitable support** is provided to senior residents
3 Inadequate provision of information on operating and maintaining LZC energy technologies		
1) 45% of householders disagree or strongly disagree that the developer or landlord has provided sufficient information on how to operate and maintain their installed technologies. 13% of householders have a neutral position on this point. 2) Some householders vaguely recall being provided with certain information, but no longer know where this is. 3) Where householders have moved out, there are cases where the new occupants have not received any information from the former occupants in relation	If householders are not in possession of adequate information on how to operate and maintain their technologies, the probability that these technologies will be operated and maintained correctly is likely to be reduced. However, it has been noted that when householders do have an instruction manual, it does not necessarily follow that this information is read or adhered to. Except for technologies that require minimal householder engagement, householders need to be sufficiently interested in	c) Consider how developers can be formally required to provide householders with appropriate user manuals for installed LZC technologies. d) To set up a borough-wide register of new homes with installed LZC energy technologies. e) To require developers to register specified details of the LZC energy technologies as installed at specific addresses with the local authority (noting that not all units in a development may have the same such technologies, or indeed any

to the technologies. 4) When asked whether the instruction manuals contain suggestions on how to make changes to household routines in order to get the most from the technologies, householders have stated that they do not. 5) The top 3 ranked obstacles to improving the performance of LZC energy technologies were as follows: - An insufficient understanding of the best operating & maint-enance procedures to follow; - Insufficient time/ability to assess and monitor the technology's performance levels; - The time & effort needed to find out how best to operate & maintain the technology.	and knowledgeable about the technologies, in order to operate and maintain them correctly and to make considered changes to their routines that enable them to fully reap the benefits from the technologies. Looking into the future, how can the local authority help ensure that, with changes in occupants, householders remain in possession of information on: - how to operate and maintain installed LZC energy technologies, - how changes to everyday routines may increase the cost-savings for householders (note that reducing energy costs was the most highly ranked incentive for improving the performance of the technologies).	such technology). Possible details to request: - Type of technology - Model number & capacity etc - Manufacturer's contact details - Web address for any down-loadable operating instructions - Installer's contact details - Recommended maintenance schedule f) To consider actively sending out succinct advice on operating and maintaining different technology types (including advice on how to make changes to household routines in order to get the most from the installed technologies), at regular intervals (e.g. every 1 to 2 years).
4 Limited degree of maintenance of LZC energy technologies		
1) The degree to which LZC energy technologies are maintained is typically very limited and irregular. Of the 23 people interviewed to date (who are responsible for their technologies), not one has been proactively approached by service providers (e.g. installers, manufacturers) in order to arrange for the servicing of their LZC energy technologies. 2) Service contracts (e.g. annual servicing) are typically not in place. One or two of those interviewed have tried to arrange for this and have found an unwillingness on the side of the installers/manufacturers to enter into such arrangements. 3) Of those interviewed, most are not aware of the recommended maintenance schedule for their installed technologies. 4) Typically, householders only have their systems checked when they believe there is a fault (as indicated by an abnormal noise, a leak, a suspected drop in	Some of the key issues to note are as follows: - the LZC energy technologies should be installed correctly, to avoid recurrent faults that frustrate householders and which may lead, at worst, to rejection, and at best to lower levels of performance; - householders are typically not aware of the recommended maintenance schedules for their technologies; - householders do not generally know how to undertake simple checks and maintenance tasks themselves; - most householders do not consider that they are knowledgeable enough to tinker with, or alter the settings for, their technologies; - installers/manufacturers of LZC energy technologies are not proactively approaching users in order to offer service contracts.	Consider the following options: g) Identify local, suitably qualified (and potentially Microgeneration Certification Scheme (MCS) registered) providers of maintenance support; h) Place details of these providers of maintenance support on the Council website; i) Inform householders that this information is available on the Council's website (e.g. using database of addresses obtained via actions (d) & (e) discussed above or via The Woking Magazine or A-Z Directory of Services); j) Consider how householders can receive training on how to undertake simple checks and maintenance tasks themselves e.g. links to training videos via the Council website, interactive webinars, ability to book one-to-one training sessions.

performance etc.). 5) Of those householders interviewed, only one maintains the installed LZC energy technology himself. There is limited evidence of installers/ developers demonstrating simple checks and maintenance tasks to householders.	The low levels of householder confidence, knowledge and perceived capability w.r.t. maintaining LZC energy technologies, combined with an underdeveloped support system from installers & manufacturers, are contributing to the current situation where the degree to which the technologies are maintained is typically very limited and irregular. This situation has implications for the on-going levels of performance which these technologies may achieve throughout their lifetime (e.g. 15-25 years).	
5 Insufficient opportunity for householders to discuss their LZC energy technologies with other users		
1) In ranking the significance of certain obstacles to improving the performance of installed technologies, an 'Insufficient opportunity to discuss your LZC energy technology with other owners' was ranked 6th out of 12. 2) For those with a low social connectedness to others with the same technology, there may be little or no opportunity to discuss their technologies with others. An example of such a case is a person moving into a single unit development, with an air source heat pump installed, who knows no other user of this technology. 3) From those interviewed, it appears that residents' associations, where set up, do **not** generally act as effective forums in which the maintenance and operation of LZC energy technologies is discussed between residents, and best practices established. 4) Approximately 25% of the 120 householders that completed the questionnaire expressed an interest in participating in some form of householder support network.	A proportion of householders live in small developments or in developments where there is little or no communication relating to installed LZC energy technologies. In these situations, and given that there may be no friends or family with similar technologies, there may be limited scope for householders to share their experiential knowledge relating to the technologies with interested others. This limits the opportunity for assisting each other with troubleshooting and for developing notions of what constitutes best practice, in terms of operation, maintenance and changing behaviours to optimise what can be gained from the technologies.	Consider the following options: k) Develop an on-line forum, linked to the Council's website, where householders can interact with each other, developing ideas for best practice and assisting each other with trouble shooting; l) Inform relevant householders of this on-line forum (using database of addresses obtained via actions (d) & (e) discussed above); m) Inform a wider audience (including those that have retrofitted their homes with LZC energy technologies) of this on-line forum via literature that is already distributed borough-wide on a regular basis (i.e. The Woking Magazine).

Table 10.2: Extract from WBC’s Climate Change Supplementary Planning Document (WBC, 2013b, p.34)
‘**Sustainable Energy in Developments for the Elderly** Applicants for developments intended for habitation by elderly residents, such as Assisted Living communities, should make special consideration for the ongoing management of any proposed LZC technologies. Points to consider include: • Ensuring any LZC technologies serve only communal areas (if technically feasible) so that individuals are not responsible for their upkeep and maintenance; and/or • Ensuring any LZC technologies are the responsibility of a facility management company to operate and maintain; and/or • Ensuring any LZC technologies are user-friendly (information and/or training might be provided to occupants to ensure they understand the technologies and whom to approach to report any faults).

The observation that my engagement with WBC worked well raised the following question: what factors had enhanced the research’s relevance to WBC? This question is explored in Section 10.7.2.

10.7.2 Achieving relevance

In this section, I crystallise out the factors that may have enabled this research to be relevant to, and impact on, local policy (discussed further in Appendix 20). The initial framework employed explores these factors under three sub-headings derived from the extant research literature: pertinence, commitment and application. I then introduce the issue of trustworthiness as an additional sub-heading worthy of consideration.

The meaning of relevance within human geography has received some attention (Dear, 1999; Pacione, 1999; Staeheli & Mitchell, 2005). Staeheli & Mitchell (2005, p.357) argue that what determines research’s relevance:

> ‘cannot be separated from the questions of *why* research should be relevant, *how* research becomes relevant, the *goals* of research, and *for whom* it is intended to be relevant’

These authors build upon work by Dear (1999) in furthering the discussion on how pertinence, commitment and application contribute to relevance. I discuss this contribution in relation to this research, filling out this framework by generating a more detailed evaluation of contributing factors.

Firstly, does this research have pertinence?

Pertinence is something which 'has significance (however defined) for a particular time and place' (Dear, 1999, p.144). This section explores the pertinence of the research by addressing issues relating to its significance, and the time and place at which it was undertaken.

Significance: In deriving the salient 'significance' factors, the research features discussed centre on its connection to a major concern of our time (Staeheli & Mitchell, 2005) and to everyday experiences of new home occupants.

The research contributes to climate change mitigation by studying how the use of LZC technologies can be improved. Where research is associated with a major issue such as climate change, the perception of its significance is enhanced by its topicality and by the contribution it can make. WBC affirms that climate change is a priority issue for them and, as a Beacon Authority[145], they are 'leading the way' (WBC, 2008, p.3). The research topic is therefore closely aligned with their priorities.

The research is grounded in householders' experiences with LZC technologies, and this focus is aligned with WBC's commitment to engage residents on the topic of climate change (WBC, 2008). This potentially adds significance to the research from WBC's perspective as it may assist with policy undertakings previously made. Furthermore, the research has particular significance to WBC as it reveals deficiencies associated with their 10% LZC energy policy, thereby bringing '*new* issues to the table' (Staeheli & Mitchell 2005, p.362). The research findings and the constructive framing of recommendations has the potential to drive improvements to policy implementation, enforcement and feedback.

In summary, the four 'significance' factors proposed as contributing to the pertinence of the research are 'topicality' (selecting a research topic that relates to a major issue), 'enabling' (enabling the achievement of undertakings made by others), 'revealing' (revealing system deficiencies) and 'constructive' (framing research findings and recommendations to facilitate productive developments in systems) (Figure 10.1).

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[145] The Beacon Scheme recognises excellence in local government.

Time: In deriving the salient 'time' factors, the features discussed centre on regulatory changes, availability of research participants, the policy development cycle and early engagement.

This research has taken place during a transformational period for the house-building sector (Section 2.3). Examining, as it does, a test-bed for the wide-spread introduction of LZC technologies into new homes, the research highlights issues other regions may encounter as tougher housing standards are introduced. As such, the research has the potential to impact on policy and processes beyond its locality.

In assessing whether the borough of Woking presented a suitable research area, the time the 10% LZC energy policy had been in place was key. With the fieldwork scheduled for 2012, this provided an adequate period of time after policy adoption (i.e. 7 years) for implementation issues to have emerged and for the number of new home occupants to be sufficient to form a basis for research.

The timing of the research was also opportune in that WBC was at a receptive stage in their policy development cycle, at which they could more readily act on recommendations arising. WBC considered that certain research recommendations could potentially be addressed by inserting additional planning guidance into their emerging Climate Change Supplementary Planning Guidance (Section 10.7.1). Thus, the research's timing was aligned with the policy development cycle, enabling particular recommendations to be implemented earlier than would otherwise be possible.

The point at which potential users of research findings are engaged with may impact on the research's relevance. Where engagement commences whilst findings are 'fresh', it may be easier to draw off aspects of the research which are of particular interest. In contrast, inundating potential users with findings that include much of irrelevance (from their perspective) may diminish the perceived relevance of the research to them. Additionally, once research findings are published, it may be harder for others to extract the most from them as details become omitted.

In conclusion, the four 'time' factors proposed as contributing to the pertinence of the research are 'predictive' (undertaking research at a time when findings can predict effects of forthcoming widespread changes), 'sufficiency' (undertaking research once sufficient data on issues has emerged), 'receptivity' (undertaking research at a receptive point in the policy development cycle) and ‘point of engagement’ (engaging early with potential users of the research) (Figure 10.1).

Place: In deriving the ‘place’ factors that have contributed to the pertinence of the research, the features discussed centre on its borough-wide extent, the nature of the user of the research findings and the influence of key individuals and groups.

Firstly, the research area was confined to a single borough, partly because it was anticipated that this would maximise the selected authority’s accountability for addressing any shortfalls highlighted. Secondly, selecting the specific jurisdiction of WBC was considered appropriate as they had received the Beacon Award for their sustainable energy approach on three occasions (WBC, 2010). As such, WBC had a reputation to maintain and this may have contributed to the pertinence of the research to them.

The last ‘place’ factor concerns a chain of individuals and groups who helped secure the research’s relevance. The first is the planning policy officer who was the WBC-contact prior to the exhibition of research findings. From initial meetings, it was apparent that the research was recognised as providing a useful policy evaluation. This officer was instrumental in marshalling key WBC personnel to the exhibition and served as the initial ‘champion’ for the research.

At the exhibition, the ‘baton’ of support was grasped by the chairperson of WBC’s Climate Change Working Group (Section 10.7.1). Subsequently, WBC adopted the recommendations and the ‘baton’ of support transferred to the wider membership of this Group. The continuous chain of advocacy from early engagement to adoption of recommendations is considered key to securing the research’s relevance.

In conclusion, the three ‘place’ factors proposed as contributing to the pertinence of the research are ‘accountability’ (selecting a research area for which there is an accountable organisation), ‘reputation’ (selecting a research area where the accountable organisation has a reputation to uphold) and ‘advocacy’ (the presence of a continuous chain of advocacy to help secure the research’s relevance) (Figure 10.1).

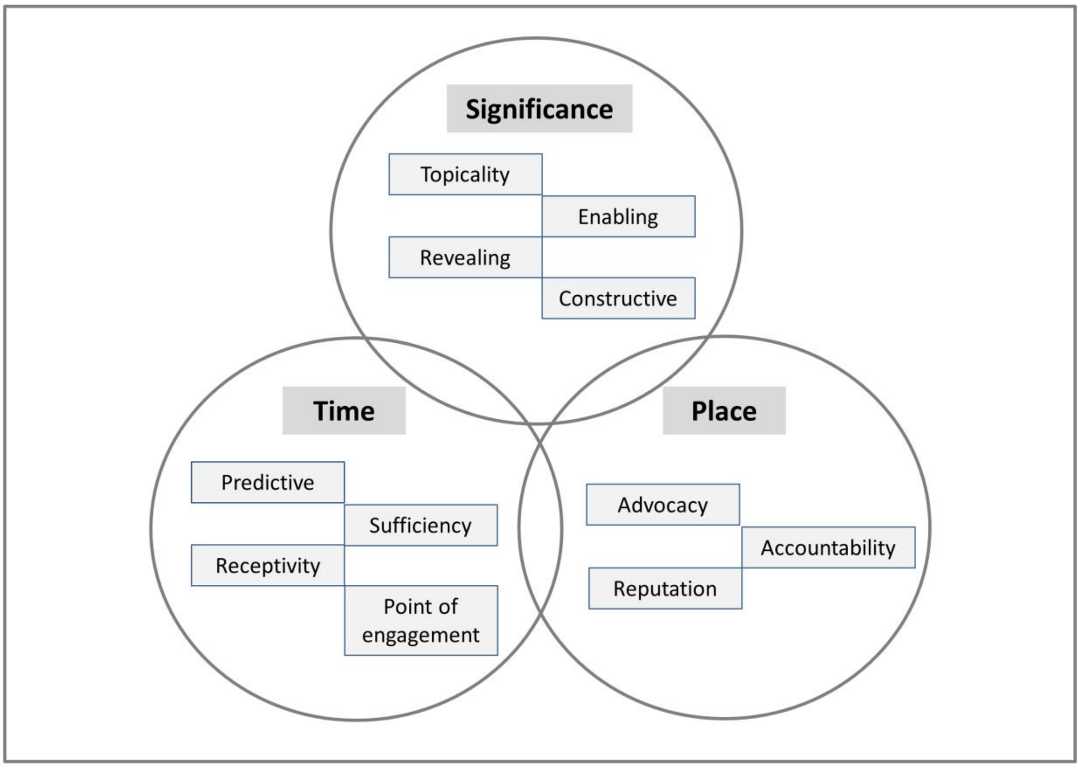

Figure 10.1. Factors contributing to the pertinence of the research

Secondly, does this research show commitment?

This next section turns to the notion of commitment:

> 'Agenda setting, contributing to concern issues, and contributing directly to the solution of some specific problem all require the making of *commitments* …' (Staeheli & Mitchell, 2005, p. 363)

For example, this commitment might manifest itself in the research questions posed or by enlisting others' support to address research findings. In deriving the 'commitment' factors that have contributed to this research's relevance, the features discussed centre on the role of moral frameworks in setting the research agenda and the role of motivation in achieving research objectives. In addition to the researcher's commitment, that of the potential users of research findings is also considered.

Commitment of the researcher: When a researcher is driven by their political commitment, their research will have personal relevance. In such instances, a researcher might experience a greater impetus to ensure their research has relevance to others. Reflecting upon my commitment, it can be viewed as an environmental commitment operating at multiple levels. On a general level, I am driven to combat the adverse environmental impacts from human activities, and at the issue level, I wish to participate in climate change mitigation efforts. At the specific level of the research project, my motivation is to contribute to understandings of how LZC technologies are being used, and to how CO_2 emission reductions can be enhanced. Thus, there may be multiple layers of commitment that underlie that manifested at the specific project level.

A researcher's commitment can influence not just the research approach but also the tenacity with which research is pursued and findings disseminated. When obstacles to progress emerge, having the commitment to deliver on the original intent of the research will promote the formulation of alternative trajectories that maintain the research's relevance, as was the case in this research (Sections 5.4.3 and 10.7.1). Thus, the researcher's commitment can have a pivotal influence at multiple stages.

Commitment of others: The commitment of collaborators may also influence the research's relevance. Here, there was early engagement with WBC, informing them of intentions and progress, and this may have heightened WBC's perception of the research's relevance to them and helped secure their engagement with the findings.

In conclusion, the four 'commitment' factors proposed as contributing to the research's relevance are 'depth of commitment' (multiple layers of commitment underlying that manifested at the project level), 'tenacity' (steadfast pursuit of research objectives and dissemination of findings), 'informed adaptability' (ability to adapt the research trajectory in response to changing circumstances) and 'commitment to engage' (early engagement with others to heighten their perception of the research's relevance to them/commitment by others to engage with the research) (Figure 10.2).

Thirdly, does this research have application?

To achieve relevance, some consider that research has 'to result in application or action' (Staeheli & Mitchell, 2005, p.364). Accordingly, findings need to be expressed in meaningful and usable terms that will lead others to act. The generation of usable knowledge is facilitated by a clear conception of who eventual users might be but, as argued by Owens (2005, p.288), the upfront identification of potential users is not straightforward. Where envisaged users belong to a single category, research questions can be framed to maximise the usability of the findings to them. Where various groups might be interested, questions are better framed to yield usable knowledge for multiple user types, employing ‘open’ as opposed to ‘targeted’ framing.

In deriving the ‘application’ factors that have contributed to this research’s relevance, the features discussed centre on the framing of research questions, findings and recommendations; and the onward application of findings.

It was envisaged that usable knowledge could be generated for a variety of groups; however, the interest that would be realised from these groups was initially unknown. As discussed in Section 10.7.1, it was representatives from WBC who expressed willingness to act on the findings and this led to a change of focus in the last fieldwork phase. To this extent, the research trajectory was responsive to the party that, firstly, recognised there was a ‘*problem calling for a solution’* (Johnston & Plummer, 2005) and, secondly, was willing to take on the responsibility of working on that solution.

It was always the intention to engage with WBC towards the end of the research in order to transfer findings to them. However, working with WBC whilst still in ‘fieldwork’ mode changed the nature and extent of this engagement to one of reflecting jointly on the findings and of thinking through how the recommendations could be operationalized. In extracting actionable findings, judgements were made on what was in WBC’s realm to address. I also prioritised what I considered to be the key recommendations from a local authority perspective (Table 10.1). This stage in the research process illustrates how researchers can play a role in optimising their work’s application, not only by framing research findings but also by framing associated recommendations.

In exploring the application of research, ascertaining how far the relevance of the research reaches may be appropriate. For example, if this research had been limited to householders with one uncommon form of technology installed (e.g. ground source heat pumps), the findings may have remained associated solely with this installation type. In contrast, if the research’s reach is considered extensive (e.g. it applies to all homes built with installed LZC technologies), then it may leverage greater impetus to act upon it as the consequences of doing so will affect a broader public. Thus, the incentive to act upon the research may be determined in part by its reach (in terms of the present and future number of ultimate ‘beneficiaries’ (Staeheli & Mitchell, 2005, p.357) of improvements).

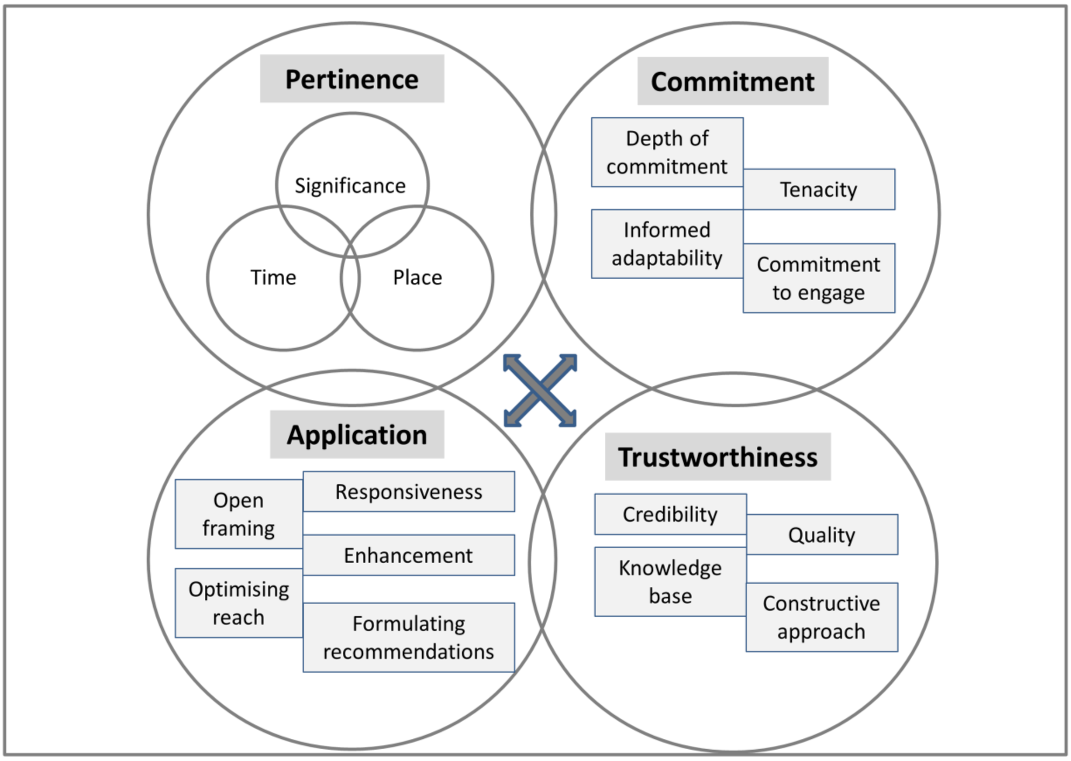

Figure 10.2. Factors contributing to the overall relevance of the research

In conclusion, the five 'application' factors proposed as contributing to the research's relevance are 'open framing' (framing research questions to yield usable knowledge for multiple user types), 'optimising reach' (selecting research questions and research participants so as to optimise the research's reach), 'responsiveness' (aligning the research trajectory in its last stage with the requirements of the party expressing the greatest interest in acting upon the findings), 'enhancement' (presenting research findings in a manner which enhances the research's relevance for interested users) and 'formulating recommendations' (formulating prioritised recommendations for action for targeted groups) (Figure 10.2).

What contribution does trustworthiness have to the relevance of research?

One aspect of relevance that appears insufficiently covered by considerations of pertinence, commitment and application is that of trustworthiness. This last section considers the significance of trustworthiness in relation to this research's relevance.

Firstly, the degree of trust in, or credibility of, a researcher is likely to affect whether others associate with the research and potentially lend their name to it, thereby endorsing its relevance. Credibility was partly attained through my affiliation to a university and through distributed materials and communication, but it was considered that an endorsement by WBC could promote a higher householder participation rate and thus this was requested. WBC agreed that I could state: 'This survey has been undertaken using information supplied by WBC'. This semi-endorsement may have increased the research's trustworthiness as perceived by would-be participants.

Secondly, the degree to which a researcher is trusted may affect the value or relevance (or 'degree of confidence' (Mountz & Walton-Roberts, 2006, p.268)) attached to the findings. The fact that the research process and myself as researcher were sufficiently trusted, helps account for the rapidity and extent to which research findings were disseminated through WBC. It also helps account for why I was asked to put forward recommendations. My experience of working in the sustainable building sector and with planning departments would have contributed to my trustworthiness as perceived by WBC. This experience afforded a good working knowledge of the sector which underpinned discussions on the research and also gave me confidence in formulating relevant recommendations.

There was also an appreciation of how policy implementation can generate unintended effects that take time to emerge and be recognised as requiring corrective actions. Such an appreciation helps researchers avoid a purely critical approach to policy processes and instead pursue a constructive one, seeking to understand not only why the unintended effects have arisen but also what changes could help prevent their continued occurrence. A constructive approach opens up possibilities for a more trusting dialogue with policy-makers as it signifies the researcher's intention to assist. This concurs with the opinion that it is 'easier to shift policy-makers' views if criticism is constructive, that is accompanied with positive suggestions for improving or changing policy' (Martin, 2001, p.200).

In conclusion, the four 'trustworthiness' factors proposed as contributing to the research's relevance are 'credibility' (attaining sufficient credibility through an affiliation to an academic establishment and via endorsement from relevant groups), 'quality' (generating material and communications that possess clarity and pertinence), 'knowledge base' (possessing a good working knowledge of the researched sector) and 'a constructive approach' (adopting an approach that assists rather than purely criticises) (Figure 10.2).

In summary, the discussion in this section has extended the extant relevance framework to incorporate trustworthiness. The range of factors proposed as contributing to this research's relevance illustrates the 'multi-faceted nature of relevance' (Staeheli & Mitchell, 2005, p.368).

10.8 Recommendations & further research

10.8.1 Recommendations

As made evident in this thesis, LZC technology-householder associations are influenced by a myriad of factors (including structural, technological, experiential, social and institutional ones) and their development should be currently viewed as an on-going process open to influence and change, where one conversation or experience, for instance, can shift householders from a technologically disengaged state to an engaged one. With this in mind, and with the desired outcome taken to be the optimisation of LZC technology, the research findings support focusing ameliorative measures on the aspects summarised in Table 10.3.

These recommendations are applicable to various stakeholders, particularly policy-makers, regulators (such as building control inspectors) and housing industry representatives (such as architects, technology designers, technology installers, sales teams and renting agents). Many of these ameliorative measures would potentially entail enrolling additional entities into the setting or by attributing additional responsibilities to those already part of the wider socio-technical network of relevance.

10.8.2 Further research

This research has focused on a cross-section of householders within a defined geographical area at a specific point in time. The main suggestion for further research would be to revisit the selected study area in the next few years to gain an appreciation of how the LZC technology-householder associations have developed. The advantages of such a longitudinal survey would be to gain a greater understanding of: (1) how successive occupants of LZC technology-fitted homes re-domesticate the technologies, including an assessment of the level of written and verbal information handed over; (2) how the LZC technologies perform over a longer time period, including further information on faults that develop; (3) whether a greater

Renting/sales process
Draw attention to LZC technology early on
Provide informed verbal advice that educates and engages householders, covering how to get the most from the technology (for example, how to use the technology in combination with conventional energy systems and how to maintain the technology)
Provide suitable written advice covering the same aspects
Consider how the transfer of information between successive occupants of LZC technology-fitted homes can be promoted.
Embedding the technology within the home
Reduce the high proportion of faulty installations currently observed
Improve commissioning and inspection procedures to improve fault detection rates
Incorporate controls and feedback devices (where possible) that are clearly readable, understandable, informative and placed in accessible, frequented spaces
Reduce the potential for high noise levels from MVHR units
Maintaining technologies
Ensure service contracts are actively offered
Contact householders soon after moving in to discuss how to monitor the performance of the technology and how to maintain it (either by themselves or using a third party)[146]
Consider how to promote the effective educating role of repair persons
Operating technologies
Contact householders soon after moving in to ensure they know how to get the most out of their technology (in financial and possibly environmental terms)
Repeat these sessions periodically to remind householders and also to capture newcomers[147]
Promote interactions between householders to facilitate the exchange of experiential knowledge

Table 10.3 Recommended ameliorative measures

proportion of householders start to monitor and maintain their technologies; (4) whether the institutional framework available to support householders in operating, maintaining and repairing their LZC technology develops further; (5) whether the role of Residents' Associations and Management Committees develops over time in relation to assisting householders with managing their technologies; and (6) whether technology-based interactions between householders within given developments increase in order to better address pertinent issues (such as repair and maintenance).

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[146] This recommendation is aligned with one from the NHBC Foundation (2011b, p.24), which advocated for 'an examination of what new aftercare processes are needed for new, energy-efficient homes'.
[147] Such 'reminder sessions' have been advocated elsewhere (NHBC Foundation, 2011b, p. 9).

The other suggestion for future research involves focusing on extra care establishments and installed LZC technology. One of the developments researched was an extra care establishment where some very elderly flat owners were given no support in operating and maintaining their STHW systems. It would be worthwhile researching additional developments for the elderly to gain a better appreciation of the prevalence and range of approaches being adopted, and whether there is a best practice approach that should be promoted.

References

Abdel-Wahab, M., Moore, D., & MacDonald, S. (2011). Exploring the adoption of low carbon technologies by Scottish housing associations. *International Journal of Low-Carbon Technologies, 6*, 318-323.

Abrahamse, W., & Steg, L. (2009). How do socio-demographic and psychological factors relate to households' direct and indirect energy use and savings? *Journal of Economic Psychology, 30*, 711-720.

Adeyeye, K., Osmani, M., & Brown, C. (2007). Energy conservation and building design. *Structural Survey, 25*(5), 375-390.

Akrich, M. (1992). The de-scription of technical objects. In W. L. Bijker, *Shaping technology/ building society* (pp. 205-224). London: MIT Press.

Akrich, M., & Latour, B. (1992). A summary of a convenient vocabulary for the semiotics of human and nonhuman assemblies. In W. Bijker, & J. Law, *Shaping technology/building society* (pp. 259-264). London: MIT Press.

Aune, M. (1996). The computer in everyday life. In M. Lie, & K. Sørensen, *Making technology our own? Domesticating technology into everyday life* (pp. 91-120). Oslo: Scandinavian University Press.

Aune, M. (2007). Energy comes home. *Energy Policy, 35*, 5457-5465.

Aune, M. (2012). Making energy visible in domestic property markets. *Building Research & Information, 40*(6), 713-723.

Bahaj, A., & James, P. (2007). Urban energy generation: the added value of photovoltaics in social housing. *Renewable and Sustainable Energy Reviews, 11*(9), 2121-2136.

Bailey, C., White, C., & Pain, R. (1999). Evaluating qualitative research. *Area, 31*(2), 169-183.

Bailey, I. (2008). Geographical work at the boundaries of climate policy. *Transactions of the Institute of British Geographers, 33*, 420-423.

Bailey, I., Gouldson, A., & Newell, P. (2011). Ecological modernisation and the governance of carbon. *Antipode, 43*(3), 682-703.

Bakardjieva, M. (2006). Domestication running wild. In T. Berker, et al., *Domestication of media and technology* (pp. 62-79). Maidenhead: Open University Press.

Banfill, P., & Peacock, A. (2007). Energy-efficient new housing. *Building Research & Information, 35*(4), 426-436.

Barnett, J., Burningham, K., Walker, G., & Cass, N. (2012). Imagined publics and engagement around renewable energy technologies in the UK. *Public Understanding of Science, 21*(1), 36-50.

Barry, A. (2013). *Material politics*. Chichester: Wiley, Blackwell.

Barstad, A. (2014). Equality is bliss? Relationship quality and the gender division of household labour. *Journal of Family Issues, 35(7),* 972-992.

Bartiaux, F. (2008). Changing energy-related practices and behaviours in the residential sector: sociological approaches. *Energy Foresight Network (EFONET) Workshop Paper WS7.2* (pp. 1-12). Madrid: CSEMAT.

Barton, J., Stephens, J., & Haslett, T. (2009). Action research. *Systemic Practice & Action Research, 22*, 475-488.

Batel, S., Devine-Wright, P., & Tangeland, T. (2013). Social acceptance of low carbon energy and associated infrastructures: a critical discussion. *Energy Policy, 58*, 1-5.

Baxter, J., & Eyles, J. (1997). Evaluating qualitative research in social geography. *Transactions of the Institute of British Geographers, 22*(4), 505-525.

Beazley, H., & Ennew, J. (2006). Participatory methods and approaches . In V. Desai, & R. Potter, *Doing Development Research* (pp. 189-199). London: Sage Publications.

Bell, M., Wingfield, J., Miles-Shenton, D., & Seavers, J. (2010). *Low carbon housing: lessons from Elm Tree Mews.* York: Joseph Rowntree Foundation.

Berg, A. (1999). A gendered socio-technical construction: the smart house. In D. MacKenzie, & J. Wajcman, *The social shaping of technology* (pp. 301-313). Buckingham: Open University Press.

Berg, A., & Lie, M. (1995). Feminism and constructivism: do artifacts have gender? *Science, Technology and Human Values, 20*(3), 332-351.

Bergman, N. (2013). Why is renewable heat in the UK underperforming? *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy, 227*(1), 124-131.

Bergman, N., et al. (2009). UK microgeneration. Part I: policy and behavioural aspects. *Proceedings of the Institution of Civil Engineers: Energy, 162*(1), 23-36.

Bergman, N., & Eyre, N. (2011). What role for microgeneration in a shift to a low carbon domestic energy sector in the UK? *Energy Efficiency, 4*(3), 335-353.

Berker, T. (2011). Domesticating spaces. *Space and Culture, 14*(3), 259-268.

Berker, T., Hartmann, M., Punie, Y., & Ward, K. (2006). Introduction. In T. Berker, et al., *Domestication of media and technology* (pp. 1-17). Maidenhead: Open University Press.

Binnie, J., Holloway, J., Millington, S., & Young, C. (2007). Mundane geographies. *Environment & Planning A, 39*, 515-520.

BIS. (2011). *The Plan for Growth.* London: Department for Business Innovation & Skills.

Boait, P. (2008). *Informed control of domestic energy systems.* PhD thesis. Leicester: De Montfort University.

Boardman, B. (2007a). Examining the carbon agenda via the 40% House scenario. *Building Research & Information, 35*(4), 363-378.

Boardman, B. (2007b). *Home truths: a low-carbon strategy to reduce UK housing emissions by 80% by 2050.* Oxford: Environmental Change Institute, University of Oxford.

Bourque, L., & Fielder, E. (1995). *How to conduct self-administered and mail surveys.* London: Sage Publications.

Bradshaw, M. (2010). Global energy dilemmas. *The Geographical Journal, 176*(4), 275-290.

Brand, R. (2005a). Urban infrastructures and sustainable social practices. *Journal of Urban Technology, 12*(2), 1-25.

Brand, R. (2005b). *Synchronising science and technology with human behaviour.* London: Earthscan.

BRE. (2008). *Viridian Solar - Clearline solar thermal field trial.* Garston: Building Research Establishment.

BRE. (2010). *SAP 2009.* Watford: Building Research Establishment.

BRE. (2011). *Technical papers supporting SAP 2012: proposed carbon emission factors and primary energy factors for SAP 2012.* Watford: Building Research Establishment.

BRE. (2014). *The Government's Standard Assessment Procedure for energy rating of dwellings: 2012 edition.* Watford: Building Research Establishment.

Brickell, K. (2012). 'Mapping' and 'doing' critical geographies of home. *Progress in Human Geography, 36*(2), 225-244.

Bridge, G., Bouzarovski, S., Bradshaw, M., & Eyre, N. (2013). Geographies of energy transition. *Energy Policy, 53*, 331-340.

Brosveet, J., & Sørensen, K. (2000). Fishing for fun and profit? *The Information Society, 16*(4), 263-276.

Broto, V., & Bulkeley, H. (2013). Maintaining climate change experiments. *International Journal of Urban and Regional Research, 37*(6), 1934-48.

Brown, G., Kraftl, P., Pickerill, J., & Upton, C. (2012). Holding the future together: towards a theorisation of the spaces and times of transition. *Environment and Planning A, 44*, 1607-1623.

Bulkeley, H. (2005). Reconfiguring environmental governance: towards a politics of scales and networks. *Political Geography, 24*, 875-902.

Bulkeley, H., Andonova, L., Bäckstrand, K., & coworkers. (2012). Governing climate change transnationally. *Environment and Planning C, 30*, 591-612.

Bulkeley, H., Hodson, M., & Marvin, S. (2012). Emerging strategies of urban reproduction and the pursuit of low carbon cities. In J. Flint, & M. Raco, *The future of sustainable cities* (pp. 113-130). Bristol: Policy Press.

Bulkeley, H., & Newell, P. (2010). *Governing climate change.* London: Routledge.

CABE. (2010). *Thinking differently - the energy hierarchy*. Retrieved December 1, 2010, from Commission for Architecture and the Built Environment: http://www.cabe.org.uk/sustainable-places/advice/the-energy-hierarchy

Cabinet Office. (2011). *Behaviour change and energy use .* London: Cabinet Office Behavioural Insights Team.

Caird, S., & Roy, R. (2008). User-centred improvements to energy efficiency products and renewable energy systems. *International Journal of Innovation Management, 12*(3), 327-355.

Caird, S., & Roy, R. (2010). Adoption and use of household microgeneration heat technologies. *Low Carbon Economy, 1*, 61-70.

Caird, S., Roy, R., & Herring, H. (2008). Improving the energy performance of UK households: results from surveys of consumer adoption and use of low- and zero-carbon technologies. *Energy Efficiency, 1*(2), 149-166.

Caird, S., Roy, R., & Potter, S. (2012). Domestic heat pumps in the UK: user behaviour, satisfaction and performance. *Energy Efficiency, 5*, 283-301.

Callon, M. (1991). Techno-economic networks and irreversibility. In J. Law, *A sociology of monsters* (pp. 132-165). London: Routledge.

Cameron, J., & Hicks, J. (2013). Performative research for a climate politics of hope. *Antipode, on-line, doi:10.1111/anti.12035*, 1-19.

Carmona, M. (2009). Design coding and the creative, market and regulatory tyrannies of practice. *Urban Studies, 46*, 2643-2667.

Carter, S., Green, J., & Thorogood, N. (2013). The domestication of an everyday health technology. *Social Theory & Health, 11*(4), 344-367.

Castro, F., Kellison, J., Boyd, S., & Kopak, A. (2010). A methodology for conducting integrative mixed methods research and data analyses. *Journal of Mixed Methods Research, 4*(4), 342-360.

Chalmers, H., & Colvin, J. (2005). Addressing environmental inequalities in UK policy: an action research perspective. *Local Environment, 10*(4), 333-360.

Chambers, R. (2002). *Participatory workshops.* London: Earthscan.

Clarke, J. (2008). The role of built environment energy efficiency in a sustainable UK energy economy. *Energy Policy, 36*, 4605-4609.

Climate Change Committee. (2008). *Building a low-carbon economy .* London: TSO.

Climate Change Committee. (2012). *Meeting carbon budgets – 2012 progress report to Parliament.* London: TSO.

Cloke, J. (2001). *The gendered household.* University of Loughborough. Microfinance Gateway.

Cochrane, A., & Ward, K. (2012). Researching the geographies of policy mobility. *Environment and Planning A, 44*, 5-12.

Cockburn, C. (1992). The circuit of technology: Gender, identity and power. In R. Silverstone, & E. Hirsch, *Consuming technologies* (pp. 32-47). London: Routledge.

Converse, J., & Presser, S. (1986). *Survey questions*. London: Sage Publications.

Cope, M. (2010). Coding qualitative data. In I. Hay, *Qualitative research methods in human geography* (pp. 281-294). Oxford: Oxford University Press.

Coutard, O., & Guy, S. (2007). STS and the city. *Science, Technology & Human Values, 32*(6), 713-734.

Crang, M. (2003). Qualitative methods: touchy, feely, look-see? *Progress in Human Geography, 27*(4), 494-504.

Creswell, J. (2009). *Research design: qualitative, quantitative, and mixed methods approaches*. London: Sage Publications.

CSE. (2012). *Make it pay while the sun shines.* Retrieved 2012 from Centre for Sustainable Energy: www.cse.org.uk/adviceleaflets

Darby, S. (2008). Energy feedback in buildings: improving the infrastructure for demand reduction. *Building Research & Information, 36*(5), 499-508.

Darby, S. (2010). Smart metering: what potential for householder engagement? *Building Research & Information, 38*(5), 442-457.

Davies, M., & Oreszczyn, T. (2012). The unintended consequences of decarbonising the built environment. *Energy and Buildings, 46*, 80-85.

Day, A., Ogumka, P., Jones, P., & Dunsdon, A. (2009). The use of the planning system to encourage low carbon energy technologies in buildings. *Renewable Energy, 34*, 2016-2021.

DCLG. (2007a). *Code for Sustainable Homes Technical Guide March 2007.* London: Department of Communities and Local Government.

DCLG. (2007b). *The Code for Sustainable Homes Technical Guide October 2007.* London: Department of Communities and Local Government.

DCLG. (2007c). *Planning Policy Statement: Planning and Climate Change - Supplement to Planning Policy Statement 1.* London: Department of Communities and Local Government.

DCLG. (2007d). *The Calcutt Review of housebuilding delivery.* London: Department of Communities and Local Government.

DCLG. (2010). *Code for Sustainable Homes Technical Guidance November 2010.* London: Department of Communities and Local Government.

DCLG. (2011). *Laying the foundations: a housing strategy for England.* London: Department of Communities and Local Government.

DCLG. (2012a). *2012 Consultation on changes to the Building Regulations in England: Section two - Part L (Conservation of fuel and power).* London: Department of Communities and Local Government.

DCLG. (2012b). *Consultation on changes to the Building Regulations in England: summary of responses.* London: Department of Communities and Local Government.

DCLG. (2013). *Next steps to zero carbon homes - Allowable Solutions.* London: Department for Communities and Local Government.

DCLG. (2014a). *Housing Standards Review: summary of responses.* London: Department for Communities and Local Government.

DCLG. (2014b). *Stephen Williams announces plans to simplify housing standards*. Press release. Accessed 24 April 2014 https://www.gov.uk/government/news/stephen-williams-announces-plans-to-raise-housing-standards

Dear, M. (1999). The relevance of postmodernism. *Scottish Geographical Magazine, 115*(2), 143-150.

DECC. (2009a). *The UK Low Carbon Transition Plan.* London: Department of Energy and Climate Change.

DECC. (2009b). *The UK Low Carbon Transition Plan - Analytical Annex.* London: Department of Energy and Climate Change.

DECC. (2010a). *National Renewable Energy Action Plan for the UK.* Retrieved January 24, 2013, from European Commission: Energy: http://ec.europa.eu/energy/renewables/action_plan_en.htm

DECC. (2010b). *Warm homes, greener homes.* London: Department of Energy and Climate Change.

DECC. (2011a). *The Carbon Plan-Annex B.* London: Department of Energy and Climate Change.

DECC. (2011b). *Microgeneration Strategy.* London: Department of Energy and Climate Change.

DECC. (2011c). *UK Renewable Energy Roadmap.* London: Department of Energy and Climate Change.

DECC. (2012a). *Energy consumption in the UK-Chapter 3: Domestic factsheet.* London: Department of Energy and Climate Change.

DECC. (2012b). *Green Deal guidance and advisory documents.* London: Department of Energy and Climate Change.

DECC. (2012c). *The future of heating.* London: Department of Energy and Climate Change.

DECC. (2012d). *Energy consumption in the UK-Chapter 3: Domestic data tables.* London: Department of Energy and Climate Change.

DECC. (2012e). *Domestic energy fact file and housing surveys: United Kingdom housing energy fact file 2012.* London: Department of Energy and Climate Change.

DECC. (2013a). *Digest of UK energy statistics.* London: Department of Energy and Climate Change.

DECC. (2013b). *UK sea level.* London: Department of Energy and Climate Change.

DECC. (2013c). *Thermal growing season in central England.* London: Department of Energy and Climate Change.

DECC. (2013d). *Central England and global surface temperature.* London: Department of Energy and Climate Change.

DECC. (2013e). *UK greenhouse gas emissions.* London: Department of Energy and Climate Change.

DECC. (2013f). *Second progress report on the promotion and use of energy from renewable sources for the UK.* London: Department of Energy and Climate Change.

DECC. (2013g). *UK Renewable Energy Roadmap - update 2013.* London: Department of Energy and Climate Change.

DECC. (2013h). *Greenhouse Gas Inventory overview factsheet.* London: Department of Energy and Climate Change.

DECC. (2013i). *UK housing energy fact file.* London: Department of Energy and Climate Change.

DECC. (2014a). *Annual statement of emissions for 2012.* London: Department of Energy and Climate Change.

DECC. (2014b). *2013 UK greenhouse gas emissions, provisional figures and 2012 UK greenhouse gas emissions, final figures by fuel type and end-user.* London: Department of Energy and Climate Change.

DECC. (2014c). *£7600 to make your home more energy efficient*. Retrieved from gov.uk: https://www.gov.uk/government/news/7600-to-make-your-home-more-energy-efficient

DEE. (2011). *Heat pumps in the UK.* Edinburgh: Delta Energy and Environment.

Defra. (2007). *England Biodiversity Strategy.* London: Department of Environment, Food and Rural Affairs.

Defra. (2008). *Climate change: action-what can you do?* Retrieved January 28, 2013, from Department of Environment, Food and Rural Affairs: http://archive.defra.gov.uk/environment/climate/action/individuals.htm

Defra. (2009). *Survey of public attitudes and behaviours towards the environment.* London: Department of Environment, Food and Rural Affairs.

Defra. (2012). *Guidelines to Defra /DECC's GHG conversion factors for company reporting.* London: Department of Environment, Food and Rural Affairs.

Devine-Wright, P. (2009). Rethinking NIMBYism: the role of place attachment and place identity in explaining place-protective action. *Journal of Community & Applied Social Psychology, 19*, 426-441.

Devine-Wright, P., Wrapson, W., Henshaw, V., & Guy, S. (2014). Low carbon heating and older adults: comfort, cosiness and glow. *Building Research & Information, 42*(3), 288-299.

Dillman, D., Smyth, J., & Christian, L. (2009). *Internet, mail, and mixed-mode surveys*. New Jersey: John Wiley & Sons.

Directgov. (2010). *Act on CO_2*. Retrieved January 28, 2013, from The National Archives: http://webarchive.nationalarchives.gov.uk/20101007164856/actonco2.direct.gov.uk/home.html

Dixon, D., & Whitehead, M. (2008). Technological trajectories: old and new dialogues in geography and technology studies. *Social & Cultural Geography, 9*(6), 601-611.

Dobbyn, J., & Thomas, G. (2005). *Seeing the light.* London: The Hub Consultants.

Dowling, R. (2010). Power, subjectivity, and ethics in qualitative research. In I. Hay, *Qualitative research methods in human geography* (pp. 26-39). Oxford: Oxford University Press.

Eadson, W. (2012). Constructions of the carbon city. In J. Flint, & M. Raco, *The future of sustainable cities* (pp. 65-86). Bristol: Policy Press.

Eisler, A., Eisler, H., & Yoshida, M. (2003). Perceptions of human ecology: cross-cultural and gender comparisons. *Journal of Environmental Psychology, 23*, 89-101.

Ekins, P., & Lees, E. (2008). The impact of EU policies on energy use in and the evolution of the UK built environment. *Energy Policy, 36*, 4580-4583.

EST. (2006a). *Solar water heating systems.* London: Energy Saving Trust.

EST. (2006b). *Demonstrating compliance.* London: Energy Saving Trust.

EST. (2010a). *Domestic low and zero carbon technologies.* London: Energy Saving Trust

EST. (2010b). *Getting warmer: a field trial of heat pumps.* London: Energy Saving Trust.

EST. (2011a). *Homing in on feed-in tariffs.* Edinburgh: Energy Saving Trust.

EST. (2011b). *Here comes the sun: a field trial of solar water heating systems.* London: Energy Saving Trust.

EST. (2013a). *Renewable Heat Premium Payment Phase 2*. Retrieved January 22, 2013, from Energy Saving Trust: http://www.energysavingtrust.org.uk/Generating-energy/Getting-money-back/Renewable-Heat-Premium-Payment-Phase-2

EST. (2013b). *Green Deal and ECO*. Retrieved February 5, 2013, from Energy Saving Trust: http://www.energysavingtrust.org.uk/Take-action/Find-a-grant/Green-Deal-and-ECO

European Parliament. (2009). Directive 2009/28/EC on the promotion of the use of energy from renewable sources. *Official Journal of the European Union*, L140/16-62.

European Parliament. (2010a). Directive 2010/30/EU on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products. *Official Journal of the European Union*, L153/1-12.

European Parliament. (2010b). Directive 2010/31/EU on the energy performance of buildings (recast). *Official Journal of the European Union, L153*, 13-35.

Faiers, A. (2009). Understanding the adoption of solar power technologies in the UK domestic sector. PhD thesis. Cranfield: Cranfield University.

Fast, S. (2013). Social acceptance of renewable energy. *Geography Compass, 7*(12), 853-866.

Faulkner, W. (1998). Review of 'Making technology our own? Domesticating technology into everyday life' by M. Lie & K. Sørensen. *Social Studies of Science, 28*(3), 484-489.

Faulkner, W. (2001). The technology question in feminism. *Women's Studies International Forum, 24*(1), 79-95.

Fink, A. (1995). *The survey handbook.* London: Sage Publications.

Fischer, J., & Guy, S. (2009). Re-interpreting regulations: architects as intermediaries for low-carbon buildings. *Urban Studies, 46*(12), 2577-2594.

Fischer, J., & Guy, S. (2011). Re-interpreting regulations: architects as intermediaries for zero carbon buildings. In S. Guy, et al., *Shaping urban infrastructures* (pp. 160-174). London: Earthscan.

Furlong, K. (2010). Small technologies, big change. *Progress in Human Geography, 35*(4), 460-482.

Gabriel, M., & Jacobs, K. (2008). The post-social turn: Challenges for housing research. *Housing Studies, 23*(4), 527-540.

Gad, C., & Jensen, C. (2010). On the consequences of post-ANT. *Science, Technology & Human Values, 35*(1), 55-80.

Georg, S. (1999). The social shaping of household consumption. *Ecological Economics, 28*, 455-466.

Ghanem, D. (2008). *Renewable energy technologies and their users: the case of solar photovoltaic technology.* PhD thesis. Newcastle: Newcastle University.

Gibson, C., Head, L., Gill, N., & Waitt, G. (2011). Climate change and household dynamics. *Transactions of the Institute of British Geographers, 36*, 3-8.

Gill, N., & Gill, M. (2012). The limits to libertarian paternalism. *Environment and Planning C, 30*, 924-940.

Gill, Z., Tierney, M., Pegg, I., & Allan, N. (2010). Low-energy dwellings: the contribution of behaviours to actual performance. *Building Research & Information, 38*(5), 491-508.

Gill, Z., Tierney, M., Pegg, I., & Allan, N. (2011). Measured energy and water performance of an aspiring low energy/carbon affordable housing site in the UK. *Energy and Buildings, 43*, 117-125.

Goodchild, B., & Walshaw, A. (2011). Towards zero carbon homes in England? From inception to partial implementation. *Housing Studies, 26*(6), 933-949.

Graham, S., & Thrift, N. (2007). Out of order: understanding repair and maintenance. *Theory, Culture & Society, 24*(3), 1-25.

Gram-Hanssen, K. (2008). Consuming technologies - developing routines. *Journal of Cleaner Production, 16*, 1181-1189.

Gram-Hanssen, K. (2010). Residential heat comfort practices: understanding users. *Building Research & Information, 38*(2), 175-186.

Gram-Hanssen, K. (2011). Understanding change and continuity in residential energy consumption. *Journal of Consumer Culture, 11*(1), 61-78.

Gram-Hanssen, K. (2013). Efficient technologies or user behaviour, which is the more important when reducing households' energy consumption? *Energy Efficiency, 6*, 447-457.

Gram-Hanssen, K., Christensen, T., & Petersen, P. (2012). Air-to-air heat pumps in real-life use. *Energy and Buildings, 53*, 64-73.

Greenhough, B. (2011). Assembling an island laboratory. *Area, 43*(2), 134-138.

Greenwood, D. (2012). The challenge of policy coordination for sustainable sociotechnical transitions: the case of the zero-carbon homes agenda in England. *Environment and Planning C, 30*, 162-179.

Guerra-Santin, O., & Itard, L. (2010). Occupants' behaviour: determinants and effects on residential heating consumption. *Building Research & Information, 38*(3), 318-338.

Guy, S., & Shove, E. (2000). *A sociology of energy, buildings and the environment.* London: Routledge.

Gyberg, P., & Palm, J. (2009). Influencing households' energy behaviour - how is this done and on what premises? *Energy Policy, 37*, 2807-2813.

Haddon, L. (2006). The contribution of domestication research to in-home computing and media consumption. *The Information Society, 22*, 195-203.

Haggett, C., & Ghanem, D. (2009). Understanding urban energy transitions as the relationships between people, process, and technology. *Draft paper for the International Roundtable Conference 'Cities and energy transitions'* (pp. 1-13). Autun, France.

Hand, M., Shove, E., & Southerton, D. (2005). Explaining showering: a discussion of the material, conventional, and temporal dimensions of practice. *Sociological Research Online, 10*(2), 1-19.

Hargreaves, T., Nye, M., & Burgess, J. (2010). Making energy visible: a qualitative field study of how householders interact with feedback from smart energy monitors. *Energy Policy, 38*, 6111-6119.

Hargreaves, T., Nye, M., & Burgess, J. (2013). Keeping energy visible? Exploring how householders interact with feedback from smart energy monitors in the long term. *Energy Policy, 52*, 126-134.

Harty, C. (2010). Implementing innovation: designers, users and actor-networks. *Technology Analysis & Strategic Management, 22*(3), 297-315.

Harwood, S. (2011). The domestication of online technologies by smaller businesses and the 'busy day'. *Information and Organization, 21*, 84-106.

Hawkesworth, M., & Imrie, R. (2009). Organisational change in systems of building regulation and control. *Environment and Planning B, 36*, 552-567.

HCA. (2011). *District heating good practice.* London: Homes and Community Agency.

Helmfrid, H., Haden, A., & Ljung, M. (2008). The role of action research in environmental research. *Systemic Practice & Action Research, 21*, 105-131.

Hemming, P. (2007). Mixing qualitative research methods in children's geographies. *Area, 40*(2), 152-162.

Hernandez, P., & Kenny, P. (2012). Net energy analysis of domestic solar water heating installations in operation. *Renewable and Sustainable Energy Reviews, 16*, 170-177.

Hill, D. (1999). *Field survey of heat recovery ventilation systems.* Retrieved 2012 from Canada Mortgage and Housing Corporation: www.cmhc-schl.gc.ca/publications/en/rh-pr/tech/96215.htm

Hill, F., Lynch, H., & Levermore, G. (2011). Consumer impacts on dividends from solar water heating. *Energy Efficiency, 4*, 1-8.

Hinchliffe, S., Kearnes, M., Degen, M., & Whatmore, S. (2007). Ecologies and economies of action - sustainability, calculations, and other things. *Environment and Planning A, 39*, 260-282.

HM Government. (2010). *Approved Document L1A: Conservation of fuel and power in new buildings.* London: HM Government

HM Government. (2013). *Approved Document L1A: Conservation of fuel and power in new dwellings. 2013 edition.* London: HM Government.

Hobson, K. (2003). Thinking habits into action: the role of knowledge and process in questioning household consumption practices. *Local Environment, 8*(1), 95-112.

Hobson, K. (2006a). Bins, bulbs, and shower timers. *Ethics, Place and Environment, 9*(3), 317-336.

Hobson, K. (2006b). Environmental responsibility and the possibilities of pragmatist-orientated research. *Social & Cultural Geography, 7*(2), 283-298.

Hondo, H., & Baba, K. (2010). Socio-psychological impacts of the introduction of energy technologies: change in environmental behaviour of households with photovoltaic systems. *Applied Energy, 87*, 229-235.

House of Commons Library. (2011). *UK Fourth Carbon Budget Briefing Paper.* London: parliament.uk

Housing Corporation. (2007). *Design and quality standards.* London: Homes and Communities Agency

Hynes, D., & Rommes, E. (2006). Fitting the internet into our lives. In T. Berker, et al., *Domestication of media and technology* (pp. 125-144). Maidenhead: Open University Press.

Ilmonen, K. (2004). The use of and commitment to goods. *Journal of Consumer Culture, 4*(1), 27-50.

Imrie, R. (2007). The interrelationships between building regulations and architects' practices. *Environment and Planning B, 34*, 925-943.

IPCC. (2013a). *IPCC Fifth Assessment Report: Climate change 2013-Physical science basis: Glossary.* Retrieved from Intergovernmental Panel on Climate Change: http://www.climatechange2013.org/images/report/WG1AR5_AnnexIII_FINAL.pdf

IPCC. (2013b). *IPCC Fifth Assessment Report: Climate change 2013-Physical science basis: Summary for policymakers.* Retrieved from Intergovernmental Panel on Climate Change: http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf

IPCC. (2013c). *Organization*. Retrieved January 22, 2013, from Intergovernmental Panel on Climate Change: http://www.ipcc.ch/organization/organization.shtml

Jagger, N., Foxon, T., & Gouldson, A. (2013). Skills constraints and the low carbon transition. *Climate Policy, 13*(1), 43-57.

Janda, K. (2011). Buildings don't use energy: people do. *Architectural Science Review, 54*(1), 15-22.

Jardine, C. (2006). *Performance of West Oxfordshire District Council office's photovoltaic arrays.* Oxford: Environmental Change Institute, Oxford University.

Jelsma, J. (2003). Innovating for sustainability. *Innovation, 16*(2), 103-116.

Jenkins, J., Nordhaus, T., & Shellenberger, M. (2011). *Energy emergence: rebound & backfire as emergent phenomena.* Oakland, USA: Breakthrough Institute.

Johnston, R., & Plummer, P. (2005). What is policy-oriented research? *Environment and Planning A, 37,* 1521.

Jones, E., Leach, M., & Wade, J. (2000). Local policies for DSM: the UK's home energy conservation act. *Energy Policy, 28*, 201-211.

Keirstead, J. (2007). Behavioural responses to photovoltaic systems in the UK domestic sector. *Energy Policy, 35*(8), 4128-4141.

Keirstead, J., & Schulz, N. (2010). London and beyond: taking a closer look at urban energy policy. *Energy Policy, 38*, 4870-4879.

Kempton, J. (2014). Asset management of LZC technology in social housing. *Structural Survey, 32*(1), 14-31.

King, G., Keohane, R., & Verba, S. (1994). *Designing social inquiry.* Princeton, New Jersey: Princeton University Press.

Kirwan, K. (2007). *Social-psychological aspects of domestic renewable energy: a study of low income tenants' responses to solar photovoltaics.* PhD thesis. Leicester: De Montfort University.

Klein, H. (1983). Changes in attitudes and behavior by using solar energy. *Journal of Economic Psychology, 4*, 167-191.

Kline, R., & Pinch, T. (1999). The social construction of technology. In D. MacKenzie, & J. Wajcman, *The social shaping of technology* (pp. 113-115). Buckingham: Open University Press.

Koch, R., & Latham, A. (2013). On the hard work of domesticating a public space. *Urban Studies, 50*(1), 6-21.

Laegran, A. (2005). Escape vehicles? In N. Oudshoorn, & T. Pinch, *How users matter: the co-construction of users and technology* (pp. 81-100). London: MIT Press.

Lagesen, A. (2012). ANT and the making of the technology in gender. *Social Studies of Science, 42*(3), 442-448.

Lane, R., & Gorman-Murray, A. (2011). Introduction. In R. Lane, & A. Gorman-Murray, *Material geographies of household sustainability* (pp. 1-16). Farnham, Surrey: Ashgate.

Latour, B. (1986). Visualisation and cognition. *Jai Press, 6,* 1-40.

Latour, B. (1992). Where are the missing masses? In W. Bijker, & J. Law, *Shaping technology/building society* (pp. 225-258). London: MIT Press.

Latour, B. (1994). On technical mediation - philosophy, sociology, genealogy. *Common Knowledge, 3*(2), 29-64.

Latour, B. (2005). *Reassembling the social.* Oxford: Oxford University Press.

Law, J. (1992). *Notes on the theory of the actor-network* (pp.379-393). Retrieved 2011, from http://heterogeneities.net/publications/Law1992NotesOnTheTheoryOfTheActorNetwork.pdf

Law, J. (1999). After ANT. In J. Law, & J. Hassard, *Actor network theory and after* (pp. 1-14). Oxford: Blackwell Publishers.

Law, J., & Callon, M. (1992). The life and death of an aircraft. In W. Bijker, & J. Law, *Shaping technology/building society* (pp. 21-52). London: MIT Press.

Law, J., & Singleton, V. (2005). Object lessons. *Organization, 12*(3), 331-355.

Leaman, A., Stevenson, F., & Bordass, B. (2010). Building evaluation: practice and principles. *Building Research & Information, 38*(5), 564-577.

Lees, T., & Sexton, M. (2014). An evolutionary innovation perspective on the selection of LZC technologies in new housing. *Building Research & Information, 42*(3), 276-287.

Lehtonen, T. (2003). The domestication of new technologies as a set of trials. *Journal of Consumer Culture, 3*(3), 363-385.

Lepawsky, J., & Mather, C. (2011). From beginnings and endings to boundaries and edges. *Area, 43*(3), 242-249.

Lie, M. (1996). Gender in the image of technology. In M. Lie, & K. Sørensen, *Making technology our own? Domesticating technology into everyday life* (pp. 201-223). Oslo: Scandinavian University Press.

Lie, M., & Sørensen, K. (1996). Making technology our own? Domesticating technology into everyday life. In M. Lie, & K. Sørensen, *Making technology our own? Domesticating technology into everyday life* (pp. 1-30). Oslo: Scandinavian University Press.

Litwin, M. (1995). *How to measure survey reliability and validity.* London: Sage Publications.

Lloyd, C., & Kerr, A. (2008). Performance of commercially available solar and heat pump water heaters. *Energy Policy, 36*, 3807-3813.

Lobley, M., Butler, A., & Winter, M. (2013). Local organic food for local people? *Regional Studies, 47*(2), 216-228.

Lockwood, M. (2013). The political sustainability of climate policy: the case of the UK Climate Change Act. *Global Environmental Change, 23*, 1339-1348.

Lombard, M. (2013). Using auto-photography to understand place. *Area, 45*(1), 23-32.

Lovell, H. (2005). Supply and demand for low energy housing in the UK: insights from a science and technology studies approach. *Housing Studies, 20*(5), 815-829.

Lovell, H. (2008). Discourse and innovation journeys: the case of low energy housing in the UK. *Technology Analysis & Strategic Management, 20*(5), 613-632.

Lovell, H. (2009). The role of individuals in policy change: the case of UK low-energy housing. *Environment and Planning C, 27*, 491-511.

Lovell, H., Bulkeley, H., & Owens, S. (2009). Converging agendas? Energy and climate change policies in the UK. *Environment and Planning C, 27*, 90-109.

Lowe, R., & Oreszczyn, T. (2008). Regulatory standards and barriers to improved performance for housing. *Energy Policy, 36*, 4475-4481.

Macintosh, A., & Steemers, K. (2005). Ventilation strategies for urban housing. *Building Research & Information, 33*(1), 17-31.

Mackay, H. (2008). Review of 'Domestication of media and technology' (2005) by Berker, et al. *European Journal of Communication, 23*, 376-379.

Mackay, H., & Gillespie, G. (1992). Extending the social shaping of technology approach: ideology and appropriation. *Social Studies of Science, 22*(4), 685-716.

MacKenzie, D., & Wajcman, J. (1999). Reproductive technology. In D. MacKenzie, & J. Wajcman, *The social shaping of technology* (pp. 269-280). Buckingham: Open University Press.

Mahapatra, K., & Gustavsson, L. (2010). Adoption of innovative heating systems . *Energy Efficiency, 3*, 1-18.

Mansouri-Azar, I. (1996). *Energy consumptions and environmental impacts of household electrical appliances.* PhD thesis. Cranfield: Cranfield University.

Marcus, G., Neumark, T., & Broome, S. (2011). *Power lines.* Royal Society for the encouragement of Arts, Manufacture and Commerce.

Marres, N. (2010). Front-staging nonhumans: publicity as a constraint on the political activity of things. In *Political Matter* (pp. 177-210). Minneapolis: Minnesota University Press.

Marres, N., & Lezuan, J. (2011). Materials and devices of the public. *Economy and Society, 40*(4), 489-509.

Martin, R. (2001). Geography and public policy: the case of the missing agenda. *Progress in Human Geography, 25*(2), 189-210.

Massey, D. (2004). Geographies of responsibility. *Geografiska Annaler, 86*(B), 5-18.

McCann, E. (2013). Policy boosterism, policy mobilities, and the extrospective city. *Urban Geography, 34*(1), 5-29.

McCann, E., & Ward, K. (2012). Assembling urbanism: following policies and 'studying through' the sites and situations of policy making. *Environment and Planning A, 44*, 42-51.

McLeod, R., Hopfe, C., & Rezgui, Y. (2012). An investigation into recent proposals for a revised definition of zero carbon homes in the UK. *Energy Policy, 46*, 25-35.

McManus, A., Gaterell, M., & Coates, L. (2010). The potential of the Code for Sustainable Homes to deliver genuine 'sustainable energy' in the UK social housing sector. *Energy Policy, 38*, 2013-2019.

McMeekin, A., & Southerton, D. (2012). Sustainability transitions and final consumption. *Technology Analysis & Strategic Management, 24*(4), 345-361.

MCS. (2014). *The Microgeneration Certification Scheme*. Retrieved March 4, 2014, from http://www.microgenerationcertification.org/

Merton Council. (2012). *The Merton Rule Conference, May 2008*. Retrieved January 17, 2013, from Merton Council: http://www.merton.gov.uk/environment/planning/planningpolicy/mertonrule/building_a_zero_carbon_future.htm

Mlecnik, E., et al. (2012). End-user experiences in nearly zero-energy houses. *Energy and Buildings, 49*, 471-478.

Monahan, J. (2013). *Housing and carbon reduction: can mainstream 'eco-housing' deliver on its low carbon promises?* PhD thesis. Norwich: University of East Anglia.

Monahan, J., & Powell, J. (2011). A comparison of the energy and carbon implications of new systems of energy provision in new build housing in the UK. *Energy Policy, 39*, 290-298.

Moore, S., & Rydin, Y. (2008). Promoting sustainable construction: European and British networks at the knowledge-policy interface. *Journal of Environmental Policy & Planning, 10*(3), 233-254.

Moss, T. (2009). Intermediaries and the governance of sociotechnical networks in transition. *Environment and Planning A, 41*, 1480-1495.

Mountz, A., & Walton-Roberts, M. (2006). Gender, geography and policy: the conundrums of engagement. *GeoJournal, 65*(4), 263-273.

Munzinger, M., Crick, F., Dayan, E., Pearsall, N., & Martin, C. (2006). *Domestic photovoltaic field trials.* London: DTI.

Murdoch, J. (1997). Towards a geography of heterogeneous associations. *Progress in Human Geography, 21*(3), 321-337.

Nassauer, J., Wang, Z., & Dayrell, E. (2009). What will the neighbors think? *Landscape and Urban Planning, 92*, 282-292.

National Housing Federation. (2010). *Lifetime costs of installing renewable energy technologies.* London: National Housing Federation

Neyland, D. (2006). Dismissed content and discontent. *Science, Technology & Human Values, 31*(1), 29-51.

NHBC Foundation. (2011a). *Guide to installation of renewable energy systems on roofs of residential buildings.* Milton Keynes: IHS BRE.

NHBC Foundation. (2011b). *How occupants behave and interact with their homes.* Milton Keynes: NHBC Foundation.

NHBC Foundation. (2012a). *Low and zero carbon homes: understanding the performance challenge.* Milton Keynes: IHS BRE.

NHBC Foundation. (2012b). *Today's attitudes to low and zero carbon homes.* Milton Keynes: NHBC Foundation.

NHBC Foundation. (2012c). *The impact of occupant behaviour and use of controls on domestic energy use.* Milton Keynes: IHS BRE.

NHBC Foundation. (2012d). *A survey of low and zero carbon technologies in new housing.* Milton Keynes: NHBC Foundation.

NHBC Foundation. (2013a). *Assessment of MVHR systems and air quality in zero carbon homes.* Milton Keynes: NHBC Foundation.

NHBC Foundation. (2013b). *Low- and zero-carbon technologies in new homes: learning from the experiences of consumers and on-site sales teams.* Milton Keynes: IHS BRE.

Norgaard, K., & York, R. (2005). Gender equality and state environmentalism. *Gender & Society, 19*, 506-522.

Nye, M., Whitmarsh, L., & Foxon, T. (2010). Sociopsychological perspectives on the active roles of domestic actors in transition to a lower carbon electricity economy. *Environment and Planning A, 42*, 697-714.

ODPM. (2004). *Planning Policy Statement 22: Renewable energy.* London: Office of the Deputy Prime Minister.

Ofgem. (2012). *Feed-in Tariff: draft guidance for renewable installations.* London: Ofgem

Organo, V., Head, L., & Waitt, G. (2012). Who does the work in sustainable households? *Gender, Place and Culture, iFirst article*, 1-19.

Ornetzeder, M., & Rohracher, H. (2006). User-led innovations and participation processes: lessons from sustainable energy technologies. *Energy Policy, 34*(2), 138-50.

Osmani, M., & O'Reilly, A. (2009a). Challenges facing housing developers to deliver zero carbon homes in England. *Proceedings of World Academy of Science, Engineering and Technology, 41*, 604-606.

Osmani, M., & O'Reilly, A. (2009b). Feasibility of zero carbon homes in England by 2016: a house builder's perpective. *Building and Environment* (44), 1917-1924.

Oudshoorn, N. (2012). How places matter: telecare technologies and the changing spatial dimensions of healthcare. *Social Studies of Science, 42*(1), 121-142.

Oudshoorn, N., & Pinch, T. (2005). How users and non-users matter. In N. Oudshoorn, & T. Pinch, *How users matter: the co-construction of users and technology* (pp. 1-25). London: MIT Press.

Oudshoorn, N., Rommes, E., & Stienstra, M. (2004). Configuring the user as everybody. *Science, Technology & Human Values, 29*(1), 30-63.

Owen, A., Mitchell, G., & Unsworth, R. (2013). Reducing carbon, tackling fuel poverty: adoption and performance of air-source heat pumps in East Yorkshire. *Local Environment, 18*(7), 817-833.

Owens, S. (2005). Making a difference? Some perspectives on environmental research and policy. *Transactions of the Institute of British Geographers, 30*(3), 287-292.

Owens, S. (2010). Learning across levels of governance: expert advice and the adoption of carbon emissions reduction targets in the UK. *Global Environmental Change, 20*, 394-401.

Owens, S., & Driffil, L. (2008). How to change attitudes and behaviours in the context of energy. *Energy Policy, 36*, 4412-4418.

Pacione, M. (1999). Guest editorial. *Scottish Geographical Journal, 115*(2), v-xiv.

Pain, R. (2003). Social geography: on action-orientated research. *Progress in Human Geography, 27*(5), 649-657.

Pain, R., Kesby, M., & Kindon, S. (2007b). Conclusion: the space(s) and scale(s) of participatory action research. In S. Kindon, R. Pain, & M. Kesby, *Participatory action research approaches and methods* (pp. 225-230). London: Routledge.

Palm, J. (2010). The public-private divide in household behaviour: how far into home can energy guidance reach? *Energy Policy, 38*, 2858-2864.

Pan, W., & Cooper, M. (2011). Decision criteria for selecting air source heat pump technology in UK low carbon housing. *Technology Analysis & Strategic Management, 23*(6), 623-637.

Pan, W., & Garmston, H. (2012a). Building regulations in energy efficiency: compliance in England and Wales. *Energy Policy, 45*, 594-605.

Pan, W., & Garmston, H. (2012b). Compliance with building regulations for new-build dwellings. *Energy, 48*, 11-22.

Paredis, E. (2011). Sustainability transitions and the nature of technology. *Foundations of Science, 16*, 195-225.

Patton, M. (2002). *Qualitative research and evaluation methods*. London: Sage Publications.

Peine, A., & Herrmann, A. (2012). The sources of use knowledge: towards integrating the dynamics of technology use and design in the articulation of societal challenges. *Technological Forecasting & Social Change, 79*, 1495-1512.

Pickvance, C. (2009). The construction of UK sustainable housing policy and the role of pressure groups. *Local Environment, 14*(4), 329-345.

Pickvance, C. (2012). Understanding UK sustainable housing policy. In J. Flint, & M. Raco, *The future of sustainable cities* (pp. 153-175). Bristol: Policy Press.

Pinch, T., & Bijker, W. (1989). The social construction of facts and artifacts. In W. Bijker, T. Hughes, & T. Pinch, *The social construction of technological systems* (pp. 17-50). London: MIT Press.

Pink, S. (2004). *Home truths: gender, domestic objects and everyday life.* Oxford: Berg.

Planning & Climate Change Coalition. (2012). *Planning for climate change - guidance for local authorities.* London: Town & Country Planning Association.

POST. (2010). *Climate change: engagement and behaviour.* London: Parliamentary Office of Science and Technology.

Powells, G. (2009). Complexity, entanglement, and overflow in the new carbon economy: the case of the UK's Energy Efficiency Commitment. *Environment and Planning A, 41*, 2342-2356.

Preda, A. (1999). The turn to things: arguments for a sociological theory of things. *The Sociological Quarterly, 40*(2), 347-366.

Pyrko, J., & Darby, S. (2011). Conditions of energy efficient behaviour - a comparative study between Sweden and the UK. *Energy Efficiency, 4*(3), 393-408.

Reason, P., Coleman, G., Ballard, D., & co-workers (2010). *Insider voices: human dimensions of low carbon technology.* Bath: Centre for Action Research, University of Bath.

Reed, M., & Christie, S. (2009). Environmental geography: we're not quite home - reviewing the gender gap. *Progress in Human Geography, 33*(2), 246-255.

Reid, L., & Houston, D. (2013). Low carbon living: a 'green' wolf in sheep's clothing? *Housing Studies, 28*(1), 1-9.

Reimer, S., & Leslie, D. (2004). Identity, consumption, and the home. *Home Cultures, 1*(2), 187-208.

Robson, C. (1993). *Real world research: a resource for social scientists and practitioner-researchers.* Oxford: Blackwell Publishers.

Rohracher, H. (2001). Managing the technological transition to sustainable construction of buildings. *Technology Analysis & Strategic Management, 13*(1), 137-150.

Rohracher, H. (2003). The role of users in the social shaping of environmental technologies. *Innovation, 16*(2), 177-192.

Rose, D., & Blume, S. (2005). Citizens as users of technology: an exploratory study of vaccines and vaccination. In N. Oudshoorn, & T. Pinch, *How users matter: the co-construction of users and technology* (pp. 103-131). London: MIT Press.

Roy, R., Caird, S., & Potter, S. (2012). People centred eco-design: consumer adoption and use of low and zero carbon products and systems. In J. Murphy, *Governing technology for sustainability* (pp. 41-62). Hoboken: Taylor and Francis.

Ruming, K. (2009). Following the actors: mobilising an actor-network methodology in geography. *Australian Geographer, 40*(4), 451-469.

Rydin, Y. (2010a). Planning and the technological society: discussing the London Plan. *International Journal of Urban and Regional Research, 34*(2), 243-259.

Rydin, Y. (2010b). *Governing for sustainable urban development.* London: Earthscan.

Rydin, Y. (2013). Using actor-network theory to understand planning practice: exploring relationships between actants in regulating low-carbon commercial development. *Planning Theory, 12*(1), 23-45.

Rydin, Y., & Turcu, C. (2014). Key trends in policy for low-energy built environments: a 20-year review. *Local Environment*, May 2014, *19*(5), 560-566.

Ryghaug, M., Sørensen, K., & Næss, R. (2011). Making sense of global warming. *Public Understanding of Science, 20*(6), 778-795.

Sætnan, A. (1996). Speaking of gender: intertwinings of a medical technology, policy debate and everyday life. In M. Lie, & K. Sørensen, *Making technology our own? Domesticating technology into everyday life* (pp. 31-63). Oslo: Scandinavian University Press.

Sayes, E. (2014). Actor-network theory and methodology: just what does it mean to say that nonhumans have agency? *Social Studies of Science, 44*(1), 134-149.

Schweber, L., & Harty, C. (2010). Actors and objects: a socio-technical networks approach to technology uptake in the construction sector. *Construction Management and Economics, 28*(6), 657-674.

Scott, A. (2009). Towards sustainable consumption: understanding the adoption and practice of environmental actions in households. PhD thesis. Sheffield: University of Sheffield.

Seeds for Change. (2009). *Facilitating meetings.* Retrieved 2013, from http://www.seedsforchange.org.uk/facilitationmeeting.pdf

Selman, P. (2000). Networks of knowledge and influence. *Town Planning Review, 71*(1), 109-121.

Sheehan, R. (2011). Actor-network theory as a reflexive tool. *Area, 43*(3), 336-342.

Shove, E. (2003). *Comfort, cleanliness and convenience.* Oxford: Berg.

Shove, E., & Chappells, H. (2001). Ordinary consumption and extraordinary relationships: utilities and their users. In J. Gronow, & A. Warde, *Ordinary consumption* (pp. 45-58). London: Routledge.

Shove, E., & Walker, G. (2010). Governing transitions in the sustainability of everyday life. *Research Policy, 39*, 471-476.

Silverstone, R. (1993). Domesticating the revolution: information and communication technologies and everyday life. *Aslib Proceedings, 45*(9), 227-233.

Silverstone, R. (2006). Domesticating domestication. Reflections on the life of a concept. In T. Berker, et al. , *Domestication of media and technology* (pp. 229-248). Maidenhead: Open University Press.

Silverstone, R., & Haddon, L. (1996). Design and the domestication of information and communication technologies. In R. Mansell, & R. Silverstone, *Communication by design* (pp. 44-74). Oxford: Oxford University Press.

Silverstone, R., Hirsch, E., & Morley, D. (1992). Information and communication technologies and the moral economy of the household. In R. Silverstone, & E. Hirsch, *Consuming technologies* (pp. 16-31). London: Routledge.

Singh, H., Muetze, A., & Eames, P. (2010). Factors influencing the uptake of heat pump technology by the UK domestic sector. *Renewable Energy, 35*, 873-878.

Smith, A., & Stirling, A. (2007). Moving outside or inside? Objectification and reflexivity in the governance of socio-technical systems. *Journal of Environmental Policy & Planning, 9*(3), 351-373.

Sørensen, K. (1997). Social shaping on the move? On the policy relevance of the social shaping of technology perspective. *STS-Working Paper 9/97*. Dragvoll: Norwegian University of Science and Technology.

Sørensen, K. (2004). Domestication: the social enactment of technology. Trondheim: Norwegian University of Science and Technology.

Sørensen, K. (2006). Domestication: the enactment of technology. Doing technology - or not. In T. Berker, et al., *Domestication of media and technology* (pp. 40-61). Maidenhead: Open University Press.

Sørensen, K., Aune, M., & Hatling, M. (2000). Against linearity - on the cultural appropriation of science and technology. In M. Dierkes, & C. von Grote, *Between understanding and trust* (pp. 237-256). Abingdon: Routledge.

Sorrell, S. (2009). Jevons' Paradox revisited: the evidence for backfire from improved energy efficiency. *Energy Policy, 37*, 1456-1469.

Southerton, D. (2006). Analysing the temporal organization of daily life. *Sociology, 40*(3), 435-454.

Southerton, D. (2013). Habits, routines and temporalities of consumption: from individual behaviours to the reproduction of everyday practices. *Time & Society, 22*(3), 335-355.

Staeheli, L., & Mitchell, D. (2005). The complex politics of relevance in geography. *Annals of the Association of American Geographers, 95*(2), 357-372.

Staffell, I., et al. (2010). UK microgeneration. Part II. *Proceedings of the Institute of Civil Engineers: Energy, 163*(4), 143-165.

Star, S. (1999). The ethnography of infrastructure. *American Behavioral Scientist, 43*(3), 377-391.

Stephenson, J., et al. (2010). Energy cultures: a framework for understanding energy behaviours. *Energy Policy, 38*, 6120-6129.

Stevenson, F., Carmona-Andreu, I., & Hancock, M. (2013). The usability of control interfaces in low-carbon housing. *Architectural Science Review, 56*(1), 70-82.

Stevenson, F., & Leaman, A. (2010). Evaluating housing performance in relation to human behaviour. *Building Research & Information, 38*(5), 437-441.

Stevenson, F., & Rijal, H. (2010). Developing occupancy feedback from a prototype to improve housing production. *Building Research & Information, 38*(5), 549-563.

Sullivan, O. (2000). The division of domestic labour: twenty years of change? *Sociology, 34*, 437-456.

Summerfield, A., & Lowe, R. (2012). Challenges and future directions for energy and buildings research. *Building Research & Information, 40*(4), 391-400.

Teddlie, C., & Yu, F. (2007). Mixed methods sampling. *Journals of Mixed Methods Research, 1*(1), 77-100.

Thaler, R., & Sunstein, C. (2009). *Nudge.* London: Penguin Books.

UK Government. (2007). *The Stamp Duty Land Tax (Zero-Carbon Homes Relief) Regulations 2007 (SI 2007 No. 3437).* London: TSO.

UK Government. (2008). *Climate Change Act 2008*. London: TSO.

UK Government. (2009a). *The Climate Change Act 2008 (2020 Target, Credit Limit and Definitions) Order 2009 (SI 2009 No.258).* London: TSO.

UK Government. (2009b). *The Carbon Accounting Regulations 2009 (SI 2009 No. 1257).* London: TSO.

UK Government. (2010). *The Building Regulations 2010 (SI 2010 No.2214).* London: TSO.

UK Government. (2012). *The Building Regulations &c. (Amendment) Regulations 2012 (SI 2012 No. 3119).* London: TSO.

UNFCCC. (1992). *Text of the Convention.* Bonn: United Nations Framework Convention on Climate Change.

UNFCCC. (1998). *Kyoto Protocol to the United Nations Framework Convention on Climate Change.* Bonn: United Nations Framework Convention on Climate Change.

UNFCCC. (2012). *Doha amendment to the Kyoto Protocol.* Bonn: United Nations Framework Convention on Climate Change.

Vale, B., & Vale, R. (2010). Domestic energy use, lifestyles and POE. *Building Research & Information, 38*(5), 578-588.

van der Pluijm, J. (2010). *The robustness and effectiveness of mechanical ventilation in airtight dwellings.* Eindhoven: Eindhoven University of Technology.

Vikkelsø, S. (2007). Description as intervention. *Science as Culture, 16*(3), 297-309.

Walker, G. (2008a). Decentralised systems and fuel poverty. *Energy Policy, 36*, 4514-4517.

Walker, G. (2008b). What are the barriers and incentives for community-owned means of energy production and use? *Energy Policy, 36*, 4401-4405.

Walker, G., & Cass, N. (2007). Carbon reduction, 'the public' and renewable energy: engaging with socio-technical configurations. *Area, 39*(4), 458-469.

Walker, G., Devine-Wright, P., Hunter, S., High, H., & Evans, B. (2010). Trust and community: Exploring the meanings, contexts and dynamics of community renewable energy. *Energy Policy, 38*, 2655-2663.

Ward, K. (2006). The bald guy just ate an orange: domestication, work and home. In T. Berker, M. Hartmann, Y. Punie, & K. Ward, *Domestication of media and technology* (pp. 145-164). Maidenhead: Open University Press.

Welsh Government. (2012). *Planning Policy Wales.* Cardiff: Welsh Government

Whitmarsh, L. (2011). Scepticism and uncertainty about climate change. *Global Environmental Change, 21*, 690-700.

Wilhite, H. (2007). Will efficient technologies save the world?. *ECEEE Summer Study* (pp. 23-30). France: ECEEE.

Wilhite, H. (2008). New thinking on the agentive relationship between end-use technologies and energy-using practices. *Energy Efficiency, 1*, 121-130.

Williams, J. (2010). The deployment of decentralised energy systems as part of the housing growth programme in the UK. *Energy Policy, 38*, 7604-7613.

Wilson, C., & Dowlatabadi, H. (2007). Models of decision making and residential energy use. *Annual Review of Environment and Resources, 32*, 169-203.

Wilson, E. (2009). Multiple scales for environmental intervention. *Planning, Practice & Research, 24*(1), 119-138.

Winchester, H., & Rofe, M. (2010). Qualitative research and its place in human geography. In I. Hay, *Qualitative research methods in human geography* (pp. 3-25). Oxford: Oxford University Press.

WBC. (2008). *Climate change strategy: think globally, act locally. 2008-2013.* Retrieved December 2, 2010, from WBC: http://www.woking.gov.uk/environment/climate/Greeninitiatives/climatechangestrategy/climatechange.pdf

WBC. (2010). *Beacon authority, tackling climate change.*Retrieved October 17, 2012 from: http://www.woking.gov.uk/environment/climate/Greeninitiatives/beacon

WBC. (2013a). *Sustainable energy in development*. Retrieved August 17, 2013, from http://www.woking.gov.uk/planning/service/energy

WBC. (2013b). *Local Development Documents: Climate Change Supplementary Planning Document,* Woking: WBC

Woolgar, S. (1991). Configuring the user. In J. Law, *A sociology of monsters.* London: Routledge.

Wrapson, W., & Devine-Wright, P. (2014). 'Domesticating' low carbon thermal technologies: diversity, multiplicity and variability in older person, off grid households. *Energy Policy, 67*, 807-817.

Wright, A. (2008). What is the relationship between built form and energy use in dwellings? *Energy Policy, 36*, 4544-4547.

WWF-UK. (2011). *Zero carbon homes. Parliamentary briefing.* Godalming: WWF-UK.

Wyatt, S. (2005). Non-users also matter. In N. Oudshoorn, & T. Pinch, *How users matter: the co-construction of users and technology* (pp. 67-79). London: MIT Press.

Yakhlef, A. (2010). The three facets of knowledge: a critique of the practice-based learning theory. *Research Policy, 39*, 39-46.

Yeager, C., & Steiger, T. (2013). Applied geography in a digital age. *Applied Geography, 39*, 1-4.

Yu, C., & Kim, J. (2012). Low-carbon housing and indoor quality. *Indoor and Built Environment, 21*(5), 5-15.

Zalejska-Jonsson, A. (2012). Evaluation of low-energy and conventional residential buildings from occupants' perspective. *Building and Environment, 58*, 135-144.

Zero Carbon Hub. (2012a). *Mechanical ventilation with heat recovery in new homes.* Milton Keynes: Zero Carbon Hub.

Zero Carbon Hub. (2012b). *Allowable solutions.* Milton Keynes: Zero Carbon Hub.

Zero Carbon Hub. (2014). *Closing the gap between design & as-built performance.* London: Zero Carbon Hub.

Zuiderent-Jerak, T., & Jensen, C. (2007). Unpacking 'intervention' in science and technology studies. *Science as Culture, 16*(3), 227-235.

Bibliography (uncited works)

Adams, C., Taylor, P., & Bell, S. (2012). Equity dimensions of micro-generation: a whole systems approach. *Journal of Renewable and Sustainable Energy, 4*, 1-19.

Adams, D. (2004). The changing regulatory environment for speculative housebuilding and the construction of core competencies for brownfield development. *Environment and Planning A, 36*, 601-624.

Adams, D. (2008). Mapping out the regulatory environment and its interaction with land and property markets. *Energy Policy, 36*, 4570-4574.

Adams, M., & Moore, G. (2007). Participatory action research and researcher safety. In S. Kindon, R. Pain, & M. Kesby, *Participatory action research approaches & methods: connecting people, participation and place* (pp. 41-48). London: Routledge.

Adger, W., Barnett, J., Brown, K., O'Brien, K., & Marshall, N. (2013). Cultural dimensions of climate change impacts and adaptation. *Nature Climate Change, 3*(2), 112-117.

Akrich, M., Callon, M., & Latour, B. (2002). The key to success of innovation Part I: The art of interessement. *International Journal of Innovation Management, 6*(2), 187-206.

Akrich, M., Callon, M., & Latour, B. (2002). The key to success of innovation Part II: The art of choosing a good spokesperson. *International Journal of Innovation Management, 6*(2), 207-225.

Allen, J., & Cochrane, A. (2010). Assemblages of state power: topological shifts in the organisation of government and politics. *Antipode, 42*(5), 1071-1089.

Allen, S. (2009). *Micro-generation for UK households: thermodynamic and related analyses. PhD thesis.* Bath: University of Bath.

Allen, S., & Hammond, G. (2010). Thermodynamic and carbon analyses of microgenerators for UK households. *Energy, 35*, 2223-2234.

Allen, S., Hammond, G., & McManus, M. (2007). Prospects for and barriers to domestic micro-generation: a United Kingdom perspective. *Applied Energy, 85*, 528-544.

Allman, L., Fleming, P., & Wallace, A. (2004). The progress of English and Welsh authorities in addressing climate change. *Local Environment, 9*(3), 271-283.

Amin, A., & Roberts, J. (2008). Knowing in action: beyond communities of practice. *Research Policy, 37*, 353-369.

Anandarajah, G., & Strachan, N. (2010). Interactions and implications of renewable and climate change policy on UK energy scenarios. *Energy Policy, 38*, 6724-6735.

Anderson, B. (2009). On geography and materiality. *Environment and Planning A, 41*, 318-335.

Anderson, B., & Adey, P. (2012). Future geographies. *Environment and Planning A, 44*(7), 1529–1535.

Anderson, B., & McFarlane, C. (2011). Assemblage and geography. *Area, 43*(2), 124-127.

Andrews, K., & Delahaye, B. (2000). Influences on knowledge processes in organizational learning: the psychosocial filter. *Journal of Management Studies, 37*(6), 797-810.

Asdal, K. (2008). Enacting things through numbers: taking nature into account/ing. *Geoforum, 39*, 123-132.

Axsen, J., & Kurani, K. (2012). Social influence, consumer behaviour, and low-carbon energy transitions. *Annual Review of Environment and Resources, 37*, 311-340.

Baba, A., Mahdjoubi, L., Olomolaiye, P., & Booth, C. (2012). Insights of architects' knowledge of the Code for Sustainable Homes in relation to low carbon housing design and delivery in the UK. *Structural Survey, 30*(5), 443-459.

Baiche, B., Walliman, N., & Ogden, R. (2006). Compliance with building regulations in England and Wales. *Structural Survey, 24*(4), 279-299.

Bailey, C., White, C., & Pain, R. (1999). Evaluating qualitative research: dealing with the tension between 'science' and 'creativity'. *Area, 31*(2), 169-183.

Bal, R., & Mastboom, F. (2009). Engaging with technologies in practice: travelling the Northwest Passage. *Science as Culture, 16*(3), 253-266.

Baldwin, M. (2006). Working together, learning together: co-operative inquiry in the development of complex practice by teams of social workers. In P. Reason, & H. Bradbury, *The handbook of action research* (pp. 221-227). London: Sage Publications

Bale, C., Foxon, T., Rucklidge, A., Hannon, M., & Gale, W. (2012). Strategic energy planning within local authorities in the UK: a study of the city of Leeds. *Energy Policy, 48*, 242-251.

Bale, C., McCullen, N., Foxon, T., Rucklidge, A., & Gale, W. (2013). Harnessing social networks for promoting adoption of energy technologies in the domestic sector. *Energy Policy, 63*, 833-844.

Ball, A., Mason, I., Grubnic, S., & Hughes, P. (2009). The carbon neutral public sector. *Public Management Review, 11*(5), 575-600.

Balta-Ozkan, N., Davidson, R., Bicket, M., & Whitmarsh, L. (2013). Social barriers to the adoption of smart homes. *Energy Policy, 63*, 363-374.

Balta-Ozkan, N., Davidson, R., Bicket, M., & Whitmarsh, L. (2013). The development of smart homes market in the UK. *Energy, 60*, 361-372.

Banks, M., & MacKian, S. (2000). Jump in! The water's warm: a comment on Peck's 'grey geography'. *Transactions of the Institute of British Geographers, 25*, 249-254.

Barr, S. (2001). Factors influencing household attitudes and behaviours towards waste management in Exeter, Devon. PhD thesis. Exeter: Exeter University.

Barr, S. (2006). Environmental action in the home: investigating the 'value-action' gap. *Geography, 37*, 906-920.

Barr, S., & Gilg, A. (2007). A conceptual framework for understanding and analysing attitudes towards environmental behaviour. *Geografiska Annaler, 89B*(4), 361-379.

Barrett, P. (2006). The early mothering project: what happened when the words 'action research' came to life for a group of midwives. In P. Reason, & H. Bradbury, *The handbook of action research* (pp. 228-235). London: Sage Publications.

Barry, A. (2006). Technological zones. *European Journal of Social Theory, 9*(2), 239-253.

Barry, A. (2008). Logics of interdisciplinarity. *Economy and Society, 37*(1), 20-49.

Barry, A., & Slater, D. (2002). Introduction: the technological economy. *Economy and Society, 31*(2), 175-193.

Bartiaux, F. (2008). Does environmental information overcome practice compartmentalisation and change consumers' behaviours? *Journal of Cleaner Production, 16*, 1170-1180.

Bartiaux, F., Vekemans, G., Gram-Hanssen, K., Maes, D., Cantaert, M., Spies, B., & Desmedt, J. (2006). *Socio-technical factors influencing residential energy consumption.* Brussels: Belgian

Science Policy. Retrieved from http://www.belspo.be/belspol/organisation/publ/pub_ostc/CPen/rappCP52_en.pdf

Beaumont, J., Loopmans, M., & Uitermark, J. (2005). Politicization of research and the relevance of geography: some experiences and reflections for an on-going debate. *Area, 37*(2), 118-126.

Beddington, J. (2008). Managing energy in the built environment: rethinking the system. *Energy Policy, 36*(12), 4299-4300.

Bellaby, P., Eames, M., & Flynn, R. (2010). The role of 'trust' in the transition to sustainable energy. *Energy Policy, 38*, 2613-2614.

Bergman, N., & Jardine, C. (2009). *Power from the people: domestic microgeneration and the Low Carbon Buildings Programme.* Oxford: Environmental Change Institute, Oxford University.

Bergman, N., Whitmarsh, L., & Köhler, J. (2008). *Transition to sustainable development in the UK housing sector: from case study to model implementation.* Norwich: Tyndall Centre for Climate Change Research.

Berry, S., Davidson, K., & Saman, W. (2014). Defining zero carbon and zero energy homes from a performance-based regulatory perspective. *Energy Efficiency, 7*, 303-322.

Berry, S., Whaley, D., Davidson, K., & Saman, W. (2014). Do the numbers stack up? Lessons from a zero carbon housing estate. *Renewable Energy, 67*, 80-89.

Bertcher, H., & Maple, F. (1977). *Creating groups.* London: Sage Publications.

Bertolini, L. (2013). Planning, the political in the everyday. *Planning Theory & Practice, 14*(1), 3-5.

Bevan, W., & Lu, S. (2012). A multidisciplinary literature review of low and zero carbon technologies into new housing. *Proceedings of the 28th Annual ARCOM (Association of Researchers in Construction Management) Conference* (pp. 1435–44). Edinburgh: ARCOM.

Bijker, W., & Law, J. (1992). General introduction. In W. Bijker, & J. Law, *Shaping technology/building society* (pp. 1-16). London: MIT Press.

Bingham, N. (2006). Bees, butterflies, and bacteria: biotechnology and the politics of nonhuman friendship. *Environment and Planning A, 38*, 483-498.

Black, N. (2001). Evidence based policy: proceed with care. *British Medical Journal, 323*, 275-279.

Blaser, M. (2014). Ontology and indigeneity: on the political ontology of heterogeneous assemblages. *Cultural Geographies, 21*(1), 49-58.

Blok, A. (2010). Topologies of climate change: actor-network theory, relational-scalar analytics, and carbon-market overflows. *Environment and Planning D, 28*, 896-912.

Blomley, N. (2004). Flowers in the bathtub: boundary crossings at the public-private divide. *Geoforum, 36*, 281-296.

Blomley, N. (2005). The borrowed view: privacy, propriety, and the entanglements of property. *Law & Social Inquiry, 30*(4), 617-661.

Blomley, N. (2008). The spaces of critical geography. *Progress in Human Geography, 32*(2), 285-293.

Blomley, N. (2010). Property, liberty and the category. *Geoforum, 41*, 353-355.

Blunt, A. (2005). Cultural geography: cultural geographies of home. *Progress in Human Geography, 29*(4), 505-515.

Boardman, B. (2005). *40% House.* Oxford: Environmental Change Institute, Oxford University.

Boccard, N. (2009). Capacity factor of wind power realized values versus estimates. *Energy Policy, 37*, 2679-2688.

Bodin, O., & Crona, B. (2009). The role of social networks in natural resource governance: what relational patterns make a difference? *Global Environmental Change, 19*, 366-374.

Bordass, B., & Leaman, A. (2005). Making feedback and post-occupancy evaluation routine: a portfolio of feedback techniques. *Building Research & Information, 33*(4), 347-352.

Boyd, A., & Paveglio, T. (2014). Front page or "buried" beneath the fold? Media coverage of carbon capture and storage. *Public Understanding of Science, 23*(4), 411-427.

Boyd, E., Boykoff, M., & Newell, P. (2011). The "new" carbon economy: what's new? *Antipode, 43*(3), 601-611.

Bradbury, H., & Reason, P. (2006). Broadening the bandwidth of validity: issues and choice-points for improving the quality of action research. In P. Reason, & H. Bradbury, *The Handbook of Action Research* (pp. 343-351). London: Sage Publications.

Bradbury-Huang, H. (2010). What is good action research? Why the resurgent interest? *Action Research, 8*(1), 93-109.

Bramfit, J. (2001). An investigation into household energy use and the utilization of wet and cold appliances. PhD thesis. Manchester: Manchester Metropolitan University.

Brand, R. (2008). Co-evolution of technical and social change in action: Hasselt's approach to urban mobility. *Built Environment, 34*(2), 182-199.

Braun, B. (2008). Environmental issues: inventive life. *Progress in Human Geography, 32*(5), 667-679.

Bray, F. (2007). Gender and technology. *Annual Review of Anthropology, 36*, 37-53.

BRE. (2011). *Draft SAP 2012.* Watford: Building Research Establishment.

Bresnen, M., & Harty, C. (2010). Objects, knowledge sharing and knowledge transformation in projects. *Construction Management and Economics, 28*(6), 549-555.

Brickell, K. (2012). Geopolitics of home. *Geography Compass, 6*(10), 575-588.

Bridge, G. (2010). Geographies of peak oil: the other carbon problem. *Geoforum, 41*, 523-530.

Browne, D., O'Regan, B., & Moles, R. (2009). Use of ecological footprinting to explore alternative domestic energy and electricity policy scenarios in an Irish city region. *Energy Policy, 37*, 2205-2213.

Buckingham, S. (2004). Ecofeminism in the twenty-first century. *The Geographical Journal, 170*(2), 146-154.

Bulkeley, H., & Betsill, M. (2005). Rethinking sustainable cities: multi-level governance and the 'urban' politics of climate change. *Environmental Politics, 14*(1), 42-63.

Bulkeley, H., & Jordan, A. (2012). Transnational environmental governance: new findings and emerging research agendas. *Environment and Planning C, 30*, 556-570.

Bulkeley, H., & Kern, K. (2006). Local government and the governing of climate change in Germany and the UK. *Urban Studies, 43*(12), 2237-2259.

Burgess, J. (2005). Commentary: Follow the argument where it leads: some personal reflections on 'policy-relevant' research. *Transactions of the Institute of British Geographers, 30*, 273-281.

Burgess, J., & Nye, M. (2008). Re-materialising energy use through transparent monitoring systems. *Energy Policy, 36*, 4454-4459.

Burnett, J. (2007). City buildings - Eco-labels and shades of green! *Landscape and Urban Planning, 83*, 29-38.

Burt, G., Entchev, E., Hammond, G., & Kelly, N. (2013). Special issue on micro-generation and related energy technologies and practices for low carbon buildings. *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy, 227*(1), 3-7.

Burton, J., & Hubacek, K. (2007). Is small beautiful? A multicriteria assessment of small-scale energy technology applications in local governments. *Energy Policy, 35*, 6402-6412.

Buzar, S., Ogden, P., & Hall, R. (2005). Households matter: the quiet demography of urban transformation. *Progress in Human Geography, 29*(4), 413-436.

CABE. (2010). *Improving the design of new housing. What role for standards?* Retrieved November 2, 2010, from webarchive.nationalarchives.gov.uk: http://webarchive.nationalarchives.gov.uk/20110118095356/http://www.cabe.org.uk/public

Cahill, C. (2007). Participatory data analysis. In S. Kindon, R. Pain, & M. Kesby, *Participatory action research approaches & methods: connecting people, participation and place* (pp. 181-187). London: Routledge.

Cahill, C. (2007). The personal is political: developing new subjectivities through participatory action research. *Gender, Place and Culture, 14*(3), 267-292.

Callon, M. (1986). Some elements of a sociology of translation: domestication of the scallops and the fisherman of St Brieuc Bay. In J. Law, *Power, action and belief: a new sociology of knowledge?* (pp. 196-223). London: Routledge.

Callon, M. (1989). Society in the making: the study of technology as a tool for sociological analysis. In W. Bijker, T. Hughes, & T. Pinch, *The social construction of technological systems* (pp. 83-103). London: MIT Press.

Callon, M. (1999). Actor-network theory - the market test. In J. Law, & J. Hassard, *Actor network theory and after* (pp. 181-195). Oxford: Blackwell Publishers.

Callon, M., & Law, J. (2005). On qualculation, agency, and otherness. *Environment and Planning D, 23*, 717-733.

Cameron, J. (2007). Linking participatory research to action: institutional challenges. In S. Kindon, R. Pain, & M. Kesby, *Participatory action research approaches & methods: connecting people, participation and place* (pp. 205-215). London: Routledge.

Cameron, J., & Gibson, K. (2005). Participatory action research in a poststructuralist vein. *Geoforum, 36*, 315-331.

Campbell, H. (2006). Is the issue of climate change too big for spatial planning? *Planning Theory & Practice, 7*(2), 201-230.

Carlile, P. (2002). A pragmatic view of knowledge and boundaries: boundary objects in new product development. *Organization Science, 13*(4), 442-455.

Carlile, P. (2004). Transferring, translating, and transforming: an integrative framework for managing knowledge across boundaries. *Organization Science, 15*(5), 555-568.

Carlsson-Kanyama, A., & Lindén, A. (2007). Energy efficiency in residences - challenges for women and men in the North. *Energy Policy, 35*, 2163-2172.

Carney, S., Whitmarsh, L., Nicholson-Cole, S., & Shackley, S. (2009). *A dynamic typology of stakeholder engagement within climate change research.* Manchester: Tyndall Centre for Climate Change Research.

Castree, N. (2002). False antitheses? Marxism, nature and actor-networks. *Antipode*, 111-146.

Castree, N. (2003). Commodifying what nature? *Progress in Human Geography, 27*(3), 273-297.

Castree, N. (2004). The geographical lives of commodities: problems of analysis and critique. *Social & Cultural Geography, 5*(1), 21-35.

Castree, N. (2005). Forum: Geography and environmental policy. Introduction. *Transactions of the Institute of British Geographers, 30*, 271-272.

Catney, P., Dobson, A., Hall, S., Hards, S., MacGregor, S., Robinson, Z., . . . Ross, S. (2013). Community knowledge networks: an action-oriented approach to energy research. *Local Environment, 18*(4), 506-520.

Cerulo, K. (2009). Nonhumans in social interaction. *Annual Review of Sociology, 35*, 531-552.

Chance, T. (2009). Towards sustainable residential communities: the Beddington Zero Energy Development (BedZED) and beyond. *Environment and Urbanization, 21*(2), 527-544.

Chatterton, P., Fuller, D., & Routledge, P. (2007). Relating action to activism: theoretical and methodological reflections. In S. Kindon, R. Pain, & M. Kesby, *Participatory action research approaches & methods: connecting people, participation and place* (pp. 216-222). London: Routledge.

Checkland, P., & Holwell, S. (1998). Action research: its nature and validity. *Systemic Practice and Action Research, 11*(1), 9-21.

Chilvers, J., & Evans, J. (2009). Understanding networks at the science-policy interface. *Geoforum, 40*, 355-362.

Chiu, L. (2006). Critical reflection: more than nuts and bolts. *Action Research, 4*(2), 183-203.

Chow, Y. (2009). Utilizing district energy system as a cost-effective measure in meeting UK domestic 'zero carbon' targets. *International Journal of Low-Carbon Technologies, 4*, 169-174.

Clarke, N., & Cochrane, A. (2013). Geographies and politics of localism: the localism of the United Kingdom's coalition government. *Political Geography, 34*, 10-23.

Cloatre, E. (2008). Trips and pharmaceutical patents in Djibouti. *Social & Legal Studies, 17*(2), 263-280.

Cochrane, A. (2010). Exploring the regional politics of 'sustainability': making up sustainable communities in the south-east of England. *Environmental Policy and Governance, 20*, 370-381.

Cockburn, C. (1997). Domestic technologies: Cinderella and the engineers. *Women's Studies International Forum, 20*(3), 361-371.

Cole, R. (2010). Green buildings and their occupants: a measure of success. *Building Research & Information, 38*(5), 589-592.

Comunian, R. (2011). Rethinking the creative city: the role of complexity, networks and interactions in the urban creative economy. *Urban Studies, 48*(6), 1157-1179.

Conan, C. (1981). *Domestic gas consumption, household behaviour patterns, and window opening. PhD thesis.* Uxbridge: Brunel University.

Cotton, M., & Devine-Wright, P. (2012). Making electricity networks "visible": industry actor representations of "publics" and public engagement in infrastructure planning. *Public Understanding of Science, 21*(1), 17-35.

Cowan, D., Morgan, K., & McDermont, M. (2009). Nominations: an actor-network approach. *Housing Studies, 24*(3), 281-300.

Cowan, R. (1989). The consumption junction: a proposal for research strategies in the sociology of technology. In W. Bijker, T. Hughes, & T. Pinch, *The social construction of technological systems* (pp. 261-280). London: MIT Press.

Crawford, J., & French, W. (2008). A low-carbon future: spatial planning's role in enhancing technological innovation in the built environment. *Energy Policy, 36*, 4575-4579.

Crosbie, T. (2006). Household energy studies: the gap between theory and method. *Energy & Environment, 17*(5), 735-753.

Cummins, S. (2003). From observation to experimentation: one prescription for a geography of public policy. *Area, 35*(2), 220-222.

Dakwale, V., & Ralegaonkar, R. (2012). Review of carbon emission through buildings: threats, causes and solution. *International Journal of Low-Carbon Technologies, 7*, 143-148.

Dalby, S. (2013). The geopolitics of climate change. *Political Geography, 37*, 38-47.

Davies, A. (2005). Local action for climate change: trans-national networks and the Irish experience. *Local Environment, 10*(1), 21-40.

DCLG. (2008). *The future of building control: consultation.* London: Department of Communities and Local Government.

DCLG. (2009). *House and planning statistics.* London: Department of Communities and Local Government.

DCLG. (2009). *Warm homes, greener homes: a strategy for household energy management.* London: Department of Communities and Local Government .

DCLG. (2010). *Carbon Reduction Delivery Plan.* London: Department of Communities and Local Government.

DCLG. (2010). *Code for Sustainable Homes and Energy Performance of Buildings: cumulative and quarterly data up to September 2010.* London: Department of Communities and Local Government.

DCLG. (2010). *Consultation on a Planning Policy Statement: Planning for a low carbon future in a changing climate.* London: Department of Communities and Local Government.

DCLG. (2013). *Housing Standards Review: consultation.* London: Department of Communities and Local Government.

de Meester, E., Zorlu, A., & Mulder, C. (2011). The residential context and the division of household and childcare tasks. *Environment and Planning A, 43*, 666-682.

DECC. (2009). *The UK Renewable Energy Strategy.* London: Department of Energy and Climate Change.

DECC. (2009). *Towards a smarter future: Government response to the consultation on electricity and gas smart metering.* London: Department of Energy and Climate Change.

DECC. (2010). *Renewable Heat Incentive.* London: Department of Energy and Climate Change.

DECC. (2010). *Smart metering implementation programme: prospectus.* London: Department of Energy and Climate Change.

DECC. (2012). *2011 UK greenhouse gas emissions, provisional figures and 2010 UK greenhouse gas emissions, final figures by fuel type and end-user. Statistical release.* London: Department of Energy and Climate Change.

DECC. (2012). *A consultation on proposed changes to the Government's Standard Assessment Procedure.* London: Department of Energy and Climate Change.

DECC. (2012). *Low Carbon Communities Challenge: evaluation report.* London: Department of Energy and Climate Change.

DECC. (2012). *UK Renewable Energy Roadmap: update 2012.* London: Department of Energy and Climate Change.

Defra. (2007). *Mobilising individual behaviour change through community initiatives: lessons for climate change .* London: Department for Environment, Food and Rural Affairs.

Demeritt, D. (2000). The new social contract for science: accountability, relevance, and value in US and UK science and research policy. *Antipode, 32*(3), 308-329.

Demeritt, D. (2002). What is the 'social construction of nature'? A typology and sympathetic critique. *Progress in Human Geography, 26*(6), 767-790.

Demeritt, D. (2004). The UK climate change programme and communication with local authorities. *Global Environmental Change, 14*, 325-336.

Demeritt, D. (2005). The promises of collaborative research. *Environment and Planning A, 37*(2), 2075–2082.

Demeritt, D. (2006). Science studies, climate change and the prospects for constructivist critique. *Economy & Society, 35*(3), 453-479.

Demeritt, D. (2009). From externality to inputs and interference: framing environmental research in geography. *Transactions of the Institute of British Geographers, 34*, 3-11.

Demeritt, D. (2009). Geography and the promise of integrative environmental research. *Geoforum, 40*, 127-129.

Demeritt, D., & Lees, L. (2005). Research relevance, 'knowledge transfer' and the geographies of CASE studentship collaboration. *Area, 37*(2), 127-137.

Demeritt, D., Dobson, A., Li, T., Leach, M., Scoones, I., & Stirling, A. (2011). Pathways to sustainability: perspectives and provocations. *Environment and Planning A, 43*, 1226-1237.

Deuble, M., & de Dear, R. (2010). *Green occupants for green buildings: the missing link.* London: Network for Comfort and Energy Use in Buildings.

Deuten, J., Rip, A., & Jelsma, J. (1997). Societal embedding and product creation management. *Technology Analysis & Strategic Management, 9*(2), 131-148.

Devine-Wright, P. (2013). Explaining "NIMBY" objections to a power line: the role of personal, place attachment and project-related factors. *Environment and Behaviour, 45*(6), 761-781.

Devine-Wright, P. (2013). Think global, act local? The relevance of place attachments and place identities in a climate change world. *Global Environmental Change, 23*, 61-69.

Devine-Wright, P., & Wiersma, B. (2013). Opening up the "local" to analysis: exploring the spatiality of UK urban decentralised energy initiatives. *Local Environment, 18*(1), 1099-1116.

Diaz-Rainey, I. (2008). *Energy policy and the take-up of 'green' energy innovations: three empirical studies on induced diffusion. PhD thesis.* Norwich: University of East Anglia.

Dick, B., Stringer, E., & Huxham, C. (2009). Theory in action research. *Action Research, 7*(1), 5-12.

Directgov. (2010). *Home Information Packs.* Retrieved October 18, 2010, from Directgov: http://www.direct.gov.uk/en/HomeAndCommunity/BuyingAndSellingYourHome/Homeinformationpacks/index.htm

Dobson, A. (2010). *Environmental citizenship and pro-environmental behaviour: rapid research and evidence review.* London: Sustainable Development Research Network.

Dodson, J. (2014). Suburbia under an energy transition: a socio-technical perspective. *Urban Studies, 51*(7), 1487-1505.

Dorling, D., & Shaw, M. (2002). Geographies of the agenda: public policy, the discipline and its (re)'turns'. *Progress in Human Geography, 26*(5), 629-641.

Dowling, R., & Power, E. (2011). Beyond McMansions and green homes: thinking household sustainability through materialities of homeyness. In R. Lane, & A. Gorman-Murray, *Material geographies of household sustainability* (pp. 75-88). Farnham: Ashgate.

Druckman, A., Chitnis, M., Sorrell, S., & Jackson, T. (2011). Missing carbon reductions? Exploring rebound and backfire effects in UK households. *Energy Policy, 39*, 3572-3581.

Durning, B., & Glasson, J. (2006). Delivering the planning system in England. *Town Planning Review, 77*(4), 457-483.

Easthants. (2010). *Energy efficiency statement.* Retrieved December 2, 2010, from East Hampshire District Council:

http://www.easthants.gov.uk/ehdc/planningforms.nsf/0/F13465B8D2D1F4888025744F004BD505/$File/Energy+Efficiency+Statements+-+requirements.pdf

Eden, S. (2005). Green, gold and grey geography: legitimating academic and policy expertise. *Transactions of the Institute of British Geographers, 30*, 282-286.

Eden, S., Tunstall, S., & Tapsell, S. (2000). Translating nature: river restoration as nature-culture. *Environment and Planning D, 18*, 257-273.

EHPA. (2010). *European heat pump statistics - outlook 2010.* Retrieved November 24, 2010, from European Heat Pump Association: http://www.ehpa.org/fileadmin/red/Heat_Pump_Statistics/EHPA_Summary_2010.pdf

Einsiedel, E., Boyd, A., Medlock, J., & Ashworth, P. (2013). Assessing socio-technical mindsets: public deliberations on carbon capture and storage in the context of energy sources and climate change. *Energy Policy, 53*, 149-158.

Eksvard, K., & Rydberg, T. (2010). Integrating participatory learning and action research and systems ecology: a potential for sustainable agriculture transitions. *Systemic Practice and Action Research, 23*, 467-486.

English Partnerships. (2007). *A review of planning and climate change.* London: English Partnerships.

Eriksson-Zetterquist, U. (2007). Gender and new technologies. *Gender, Work and Organization, 14*(4), 305-311.

EST. (2005). *Potential for microgeneration: study and analysis.* London: Energy Saving Trust.

EST. (2007). *Energy in planning and building control: Merton's renewable energy planning condition.* London: Energy Saving Trust.

EST. (2007). *The ampere strikes back: how consumer electronics are taking over the world.* London: Energy Saving Trust.

EST. (2008). *Energy efficiency and the Code for Sustainable Homes Level 4.* London: Energy Saving Trust.

EST. (2008). *Review of energy services in the domestic sector.* London: Energy Saving Trust.

EST. (2009). *Building Regulations in England & Wales.* London: Energy Saving Trust.

EST. (2010). *Feed-in-Tariff scheme.* London: Energy Saving Trust.

EST. (2010). *Social housing.* London: Energy Saving Trust.

EST. (2010). *The Nottingham Declaration on climate change.* London: Energy Saving Trust.

EST. (2011). *The carbon cutter.* London: Energy Saving Trust.

Etkin, D., & Ho, E. (2007). Climate change: perceptions and discourses of risk. *Journal of Risk Research, 10*(5), 623-641.

Evans, J. (2006). Lost in translation? Exploring the interface between local environmental research and policy making. *Environment and Planning A, 38*, 517-531.

Farias, I., & Bender, T. (2010). Introduction: decentring the object of urban studies. In I. Farias, & T. Bender, *Urban assemblages* (pp. 1-24). London: Routledge.

Feenberg, A. (2010). Ten paradoxes of technology. *Techné, 14*(1), 3-15.

Filho, W. (2008). Communicating climate change: challenges ahead and action needed. *International Journal of Climate Change Strategies and Management, 1*(1), 6-18.

Fine, B. (2005). From actor-network theory to political economy. *Capitalism Nature Socialism, 16*(4), 91-108.

Fink, A. (1995). *How to analyze survey data.* London: Sage Publications.

Fink, A. (1995). *How to ask survey questions.* London: Sage Publications.

Fleming, P., & Webber, P. (2004). Local and regional greenhouse gas management. *Energy Policy, 32*, 761-771.

Flood, R. (2006). The relationship of 'systems thinking' to action research . In P. Reason, & H. Bradbury, *The handbook of action research* (pp. 117-128). London: Sage Publications.

Fox, S. (2000). Communities of practice, Foucault and actor-network theory. *Journal of Management Studies, 37*(6), 853-867.

Frey, B., & Jegen, R. (2000). *Motivation crowding theory: a survey of empirical evidence (revised version).* Zurich: University of Zurich.

Frey, B., & Stutzer, A. (2006). *Environmental morale and motivation.* Zurich: University of Zurich.

Fuentes, C. (2014). Green materialities: marketing and the socio-material construction of green products. *Business Strategy and the Environment, 23*, 105-116.

Fuller, D. (2008). Public geographies: taking stock. *Progress in Human Geography, 32*(6), 834-844.

Fuller, R., & Aye, L. (2012). Human and animal power: the forgotten renewables. *Renewable Energy, 48*, 326-332.

Furbo, S., Andersen, E., Knudsen, S., Vejen, N., & Shah, L. (2005). Smart solar tanks for small solar domestic hot water systems. *Solar Energy, 78*, 269-279.

Gareau, B. (2005). We have never been human: agential nature, ANT, and marxist political ecology. *Capitalism Nature Socialism, 16*(4), 127-140.

Garrety, K., & Badham, R. (2004). User-centred design and the normative politics of technology. *Science, Technology and Human Values, 29*(2), 191-212.

Gausdal, A., & Hildrum, J. (2012). Facilitating trust building in networks: a study from the water technology industry. *Systemic Practice and Action Research, 25*, 15-38.

Gaventa, J., & Cornwall, A. (2006). Power and knowledge. In P. Reason, & H. Bradbury, *The handbook of action research* (pp. 71-82). London: Sage Publications.

Geels, F. (2011). The multi-level perspective on sustainability transitions: responses to seven criticisms. *Environmental Innovation and Societal Transitions, 1*, 24-40.

Geels, F., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research Policy, 36*, 399-417.

Ghanem, D., & Haggett, C. (2010). Shaping people's engagement with microgeneration technology: the case of solar photovoltaics in UK homes. In P. Devine-Wright, *Renewable Energy and the Public* (pp. 149-166). London: Earthscan.

Ghazi, S., & Ip, K. (2014). The effect of weather conditions on the efficiency of PV panels in the southeast of UK. *Renewable Energy, 69*, 50-59.

Ghertner, D. (2006). Technology and tricks: intra-household technology implementation and gender struggles. *Gender, Technology and Development, 10*(3), 281-311.

GLA. (2010). *Delivering London's energy future: draft climate change mitigation and energy strategy.* Retrieved November 25, 2010, from london.gov.uk: http://legacy.london.gov.uk/mayor/priorities/docs/delivering_london_energy_future_assembly_and_functional_body_draft_february_2010.pdf

Glass, J., Dainty, A., & Gibb, A. (2008). New build: materials, techniques, skills and innovation. *Energy Policy, 36*, 4534-4538.

Gorman-Murray, A. (2008). Masculinity and the home: a critical review and conceptual framework. *Australian Geographer, 39*(3), 367-379.

Gram-Hanssen, K. (2010). Standby consumption in households analysed with a practice theory approach. *Journal of Industrial Ecology, 14*(1), 150-165.

Gram-Hanssen, K. (2012). Air-to-air heat pumps in real-life use: are potential savings achieved or are they transformed into increased comfort? *Energy and Buildings, 53*, 64-73.

Granovetter, M. (1973). The strength of weak ties. *American Journal of Sociology, 78*(6), 1360-1380.

Green Alliance. (2011). *Avoiding gas lock-in: why a second dash for gas is not in the UK's interest.* London: Green Alliance.

Green Alliance. (2011). *Bringing it home: using behavioural insights to make green living policy work.* London: Green Alliance.

Greening, B., & Azapagic, A. (2012). Domestic heat pumps: life cycle environmental impacts and potential implications for the UK. *Energy, 39*, 205-217.

Greening, B., & Azapagic, A. (2014). Domestic solar thermal water heating: a sustainable option for the UK? *Renewable Energy, 63*, 23-36.

Gregson, N., Metcalfe, A., & Crewe, L. (2009). Practices of object maintenance and repair: how consumers attend to consumer objects within the home. *Journal of Consumer Culture, 9*(2), 248-272.

Grunwald, A. (2007). Working towards sustainable development in the face of uncertainty and incomplete knowledge. *Journal of Environmental Policy & Planning, 9*(3), 245-262.

Gubbins, C., & MacCurtain, S. (2008). Understanding the dynamics of collective learning: the role of trust and social capital. *Advances in Developing Human Resources, 10*(4), 578-599.

Gul, M., & Menzies, G. (2012). Designing domestic buildings for future summers: attitudes and opinions of building professionals. *Energy Policy, 45*, 752-761.

Gupta, N., Fischer, A., & Frewer, L. (2012). Socio-psychological determinants of public acceptance of technologies: a review. *Public Understanding of Science, 21*(7), 782-795.

Gupta, R., & Chandiwala, S. (2009). Achieving low carbon buildings using Code for Sustainable Homes in the UK. *International Journal of Low-Carbon Technologies, 4*, 187-196.

Gupta, R., & Chandiwala, S. (2010). Understanding occupants: feedback techniques for large-scale low-carbon domestic refurbishments. *Building Research & Information, 38*(5), 530-548.

Gustavsen, B. (2006). Theory and practice: the mediating discourse. In P. Reason, & H. Bradbury, *The handbook of action research* (pp. 17-26). London: Sage Publications.

Guy, S. (2006). Designing urban knowledge: competing perspectives on energy and buildings. *Environment and Planning C, 24*, 645-659.

Guy, S. (2010). Pragmatic ecologies: situating sustainable building. *Architectural Science Review, 53*(1), 21-28.

Haas, R., Ornetzeder, M., Hametner, K., Wroblewski, A., & Hübner, M. (1999). Socio-economic aspects of the Austrian 200 kWp-photovoltaic-rooftop programme. *Solar Energy, 66*(3), 183-191.

Hache, E., & Latour, B. (2010). Morality or moralism? *Common Knowledge, 16*(2), 311-330.

Haddon, L. (2006). Empirical studies using the domestication framework. In T. Berker, M. Hartmann, Y. Punie, & K. Ward, *Domestication of media and technology* (pp. 103-122). Maidenhead: Open University Press.

Haddon, L. (2007). Roger Silverstone's legacies: domestication. *New Media Society, 9*(1), 25-32.

Hadfield-Hill, S. (2013). Living in a sustainable community: new spaces, new behaviours? *Local Environment, 18*(3), 354-371.

Hall, S. (2011). Exploring the 'ethical everyday': an ethnography of the ethics of family consumption. *Geoforum, 42*, 627-637.

Hamilton, I., Summerfield, A., Lowe, R., Ruyssevelt, P., Elwell, C., & Oreszczyn, T. (2013). Energy epidemiology: a new approach to end-use energy demand research. *Building Research & Information, 41*(4), 482-497.

Hammond, G., & Pearson, P. (2013). Challenges of the transition to a low carbon, more electric future: from here to 2050. *Energy Policy, 52*, 1-9.

Hamza, N., & Greenwood, D. (2009). Energy conservation regulations: impacts on design and procurement of low energy buildings. *Building and Environment, 44*(5), 929-936.

Hand, M., Shove, E., & Southerton, D. (2007). Home extensions in the United Kingdom: space, time, and practice. *Environment and Planning D, 25*, 668-681.

Hards, S. (2011). Social practice and the evolution of personal environmental values. *Environmental Values, 20*, 23-42.

Hards, S. (2013). Status, stigma and energy practices in the home. *Local Environment, 18*(4), 438-454.

Hargreaves, T., Longhurst, N., & Seyfang, G. (2013). Up, down, round and round: connecting regimes and practices in innovation for sustainability. *Environment and Planning A, 45*, 402-420.

Harrison, C., & Popke, J. (2011). "Because you got to have heat": the networked assemblage of energy poverty in Eastern North Carolina. *Annals of the Association of American Geographers, 101*(4), 949-961.

Hartmann, M. (2006). The triple articulation of ICTs. Media as technological objects, symbolic environments and individual texts. In T. Berker, M. Hartmann, Y. Punie, & K. Ward, *Domestication of media and technology* (pp. 80-102). Maidenhead: Open University Press.

Harvey, L. (2009). Reducing energy use in the buildings sector: measures, costs, and examples. *Energy Efficiency, 2*, 139-163.

Haughton, G., & Counsell, D. (2004). Regions and sustainable development: regional planning matters. *The Geographical Journal, 170*(2), 135-145.

Hawkins, G. (2011). Interrogating the household as a field of sustainability. In R. Lane, & A. Gorman-Murray, *Material geographies of household sustainability* (pp. 69-72). Farnham: Ashgate.

Hawkins, G. (2011). Packaging water: plastic bottles as market and public devices. *Economy and Society, 40*(4), 534-552.

Hay, I. (2010). *Qualitative research methods in human geography* (3rd ed.). Oxford: Oxford University Press.

Head, L., Farbotko, C., Gibson, C., Gill, N., & Waitt, G. (2013). Zones of friction, zones of traction: the connected household in climate change and sustainability policy. *Australasian Journal of Environmental Management, 20*(4), 351-362.

Hendrickson, D., & Wittman, H. (2010). Post-occupancy assessment: building design, governance and household consumption. *Building Research & Information, 38*(5), 481-490.

Henning, A. (2004). Social anthropological and interdisciplinary research on the conversion of electrically heated single family houses to heating by combined pellet-solar systems. *Biomass and Bioenergy, 27*, 547-555.

Henning, A. (2005). Climate change and energy use: the role for anthropological research. *Anthropology Today, 21*(3), 8-12.

Herbert, S. (2000). For ethnography. *Progress in Human Geography, 24*(4), 550-568.

Heron, J., & Reason, P. (2006). The practice of co-operative inquiry: research 'with' rather than 'on’ people. In P. Reason, & H. Bradbury, *The handbook of action research* (pp. 144-154). London: Sage Publications.

Herring, H., Caird, S., & Roy, R. (2007). Can consumers save energy? Results from surveys of consumer adoption and use of low and zero carbon technologies. *ECEEE 2007 Summer Study* (pp. 1885-1895). La Colle sur Loup, France: ECEEE.

Hess, M. (2008). Governance, value chains and networks: an afterword. *Economy and Society*, 452-459.

Higgins, M. (2007). Raising the standard: design skills for practising planners. *Town & Planning Review, 77*(5), 605-624.

Hinchliffe, S. (1996). Helping the Earth begins at home. *Global Environmental Change, 6*(1), 53-62.

Hinchliffe, S., Kearnes, M., Degen, M., & Whatmore, S. (2007). Ecologies and economies of action - sustainability, calculations, and other things. *Environment and Planning A, 39*, 260-282.

Hinnells, M. (2008). Technologies to achieve demand reduction and microgeneration in buildings. *Energy Policy, 36*, 4427-4433.

Hobson, K. (2011). Environmental politics, green governmentality and the possibility of a 'creative grammer' for domestic sustainabile consumption. In R. Lane, & A. Gorman-Murray, *Material geographies of household sustainability* (pp. 193-210). Farnham: Ashgate.

Holifield, R. (2009). Actor-network theory as a critical approach to environmental justice. *Antipode, 41*(4), 637-658.

Hostetler, M., & Noiseux, K. (2010). Are green residential developments attracting environmentally savvy homeowners? *Landscape and Urban Planning, 94*, 234-243.

House of Commons Environmental Audit Committee. (2013). *Code for Sustainable Homes and the Housing Standards Review.* London: House of Commons.

Housing Learning and Improvement Network. (2008). *Extra care housing - what is it?* Retrieved March 10, 2014, from http://www.housinglin.org.uk/_library/Resources/Housing/Housing_advice/Extra_Care_Housing_-_What_is_it.pdf

Hudson, R. (2007). Region and place: rethinking regional development in the context of global environmental change. *Progress in Human Geography, 31*, 827-836.

Huebner, G., Cooper, J., & Jones, K. (2013). Domestic energy consumption: what role do comfort, habit, and knowledge about the heating system play? *Energy and Buildings, 66*, 626-636.

Hughes, N., & Strachan, N. (2010). Methodological review of UK and international low carbon scenarios. *Energy Policy, 38*, 6056-6065.

Hughes, T. (1986). The seamless web: technology, science, etcetera, etcetera. *Social Studies of Science, 16*(2), 281-292.

Hulme, M. (2008). Geographical work at the boundaries of climate change. *Transactions of the Institute of British Geographers, 33*, 5-11.

Hulme, M. (2010). Cosmopolitan climates: hybridity, foresight and meaning. *Theory, Culture & Society, 27*(2-3), 267-276.

Hulme, M. (2010). Problems with making and governing global kinds of knowledge. *Global Environmental Change, 20*, 558-564.

Hulme, M., & Turnpenny, J. (2004). Understanding and managing climate change: the UK experience. *The Geographical Journal, 170*(2), 105-115.

Huxley, M. (2006). Spatial rationalities: order, environment, evolution and government. *Social & Cultural Geography, 7*(5), 771-787.

Huzzard, T., Ahlberg, M., & Ekman, M. (2010). Constructing interorganizational collaboration: the action researcher as boundary subject. *Action Research, 8*(3), 293-314.

Imrie, R. (2004). Urban geography, relevance, and resistance to the "policy turn". *Urban Geography, 25*(8), 697-708.

Imrie, R., & Street, E. (2009). Risk, regulation and the practices of architects. *Urban Studies, 46*, 2555-2576.

Imrie, R., & Street, E. (2009). Regulating design: the practices of architecture, governance and control. *Urban Studies, 46*, 2507-2518.

Ingram, J., Shove, E., & Watson, M. (2007). Products and practices: selected concepts from science and technology studies and from social theories of consumption and practice. *Design Issues, 23*(2), 3-16.

IPCC. (2007). *Glossary of Terms used in the IPCC Fourth Assessment Report.* Retrieved January 24, 2013, from Intergovernmental Panel on Climate Change: http://www.ipcc.ch/publications_and_data/publications_and_data_glossary.shtml

IPCC. (2007). *IPCC Fourth Assessment Report: Climate change 2007-Synthesis report.* Retrieved January 22, 2013, from Intergovernmental Panel on Climate Change: http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

Isiadinso, C., Goodhew, S., Marsh, J., & Hoxley, M. (2011). Identifying an appropriate approach to judge low carbon buildings. *Structural Survey, 29*(5), 436-446.

Jack, S. (2005). The role, use and activation of strong and weak network ties: a qualitative analysis. *Journal of Management Studies, 42*(6), 1233-1240.

James, A., Gray, M., Martin, R., & Plummer, P. (2004). Commentary: (Expanding) the role of geography in public policy. *Environment and Planning A, 36*, 1901-1905.

Jasanoff, S. (2013). A political history of STS. In A. Barry, & G. Born, *Interdisciplinarity: reconfigurations of the social and natural sciences* (pp. 99-118). London: Routledge.

Jenkins, D., Tucker, R., & Rawlings, R. (2009). Modelling the carbon-saving performance of domestic ground-source heat pumps. *Energy and Buildings, 41*, 587-595.

Jensen, C. (2009). Sorting attachments: usefulness of STS in healthcare practice and policy. *Science as Culture, 16*(3), 237-251.

Johnson, J. (1988). Mixing humans and non-humans together: the sociology of a door-closer. *Social Problems, 35*(3), 298-310.

Jones, P., Patterson, J., & Lannon, S. (2007). Modelling the built environment at an urban scale: energy and health impacts in relation to housing. *Landscape and Urban Planning, 83*, 39-49.

Jöns, H. (2006). Dynamic hybrids and the geographies of technoscience. *Social & Cultural Geography, 7*(4), 559-580.

Jordan, U., & Furbo, S. (2005). Thermal stratification in small solar domestic storage tanks caused by draw-offs. *Solar Energy, 78*, 291-300.

Joss, S. (2010). Accountable governance, accountable sustainability? A case study of accountability in the governance for sustainability. *Environmental Policy and Governance, 20*, 408-421.

Juntti, M., Russel, D., & Turnpenny, J. (2009). Evidence, politics and power in public policy for the environment. *Environmental Science & Policy, 12*, 207-215.

Kadi, S. (2013). *Technology in everyday life: an exploration of gender and age in internet use. PhD thesis.* Middlesborough: Teesside University.

Kaika, M. (2004). Interrogating the geographies of the familiar: domesticating nature and constructing the autonomy of the modern home. *International Journal of Urban and Regional Research, 28*(2), 265-286.

Kaika, M., & Swyngedouw, E. (2000). Fetishing the modern city: the phantasmagoria of urban technological networks. *International Journal of Urban and Regional Research, 24*(1), 120-138.

Karlin, B., Ford, R., & Squiers, C. (2014). Energy feedback technology: a review and taxonomy of products and platforms. *Energy Efficiency, 7*, 377-399.

Keirstead, J. (2006). Evaluating the applicability of integrated domestic energy consumption frameworks in the UK. *Energy Policy, 34*, 3065-3077.

Keirstead, J. (2007). The UK domestic photovoltaics industry and the role of central government. *Energy Policy, 35*, 2268-2280.

Keirstead, J. (2008). What changes, if any, would increased levels of low-carbon decentralised energy have on the built environment? *Energy Policy, 36*, 4518-4521.

Kelly, S. (2011). Do homes that are more energy efficient consume less energy? A structural equation model of the English residential sector. *Energy, 36*, 5610-5620.

Kelly, S., & Pollitt, M. (2010). An assessment of the present and future opportunities for combined heat and power with district heating in the United Kingdom. *Energy Policy, 38*, 6936-6945.

Kelly, S., Crawford-Brown, D., & Pollitt, M. (2012). Building performance evaluation and certification in the UK: is SAP fit for purpose? *Renewable and Sustainable Energy Reviews, 16*, 6861-6878.

Kennedy, E. (2011). Rethinking ecological citizenship: the role of neighbourhood networks in cultural change. *Environmental Politics, 20*(6), 843-860.

Kesby, M. (2007). Spatialising participatory approaches: the contribution of geography to a mature debate. *Environment and Planning A, 39*, 2813-2831.

Kesby, M., Kindon, S., & Pain, R. (2007). Participation as a form of power: retheorising empowerment and spatialising participatory action research. In S. Kindon, R. Pain, & M. Kesby, *Participatory action research approaches and methods: connecting people, participation and place.* London: Routledge.

Killip, G. (2013). Transition management using a market transformation approach: lessons for theory, research, and practise from the case of low-carbon housing refurbishment in the UK. *Environment and Planning C, 31*, 876-892.

Kindon, S., Pain, R., & Kesby, M. (2007). Introduction: connecting people, participation and place. In S. Kindon, R. Pain, & M. Kesby, *Participatory action research approaches & methods: connecting people, participation and place* (pp. 1-6). London: Routledge.

Kindon, S., Pain, R., & Kesby, M. (2007). Participatory action research: origins, approaches and methods. In S. Kindon, R. Pain, & M. Kesby, *Participatory action research approaches & methods: connecting people, participation and place* (pp. 9-18). London: Routledge.

Kirsch, S., & Mitchell, D. (2004). The nature of things: dead labor, nonhuman actors, and the persistence of marxism. *Antipode, 36*(4), 687-705.

Klein, H., & Kleinman, D. (2002). The social construction of technology: structural considerations. *Science, Technology and Human Values, 27*(1), 28-52.

Klessmann, C., Lamers, P., Ragwitz, M., & Resch, G. (2010). Design options for cooperation mechanisms under the new European renewable energy directive. *Energy Policy, 38*, 4679-4691.

Kline, R. (2005). Resisting consumer technology in rural America: the telephone and electrification. In N. Oudshoorn, & T. Pinch, *How users matter: the co-construction of users and technology* (pp. 51-66). London: MIT Press.

Knudsen, S. (2002). Consumers' influence on the thermal performance of small SDHW systems - theoretical investigations. *Solar Energy, 73*(1), 33-42.

Koschmann, T., Kuutti, K., & Hickman, L. (1998). The concept of breakdown in Heidegger, Leont'ev, and Dewey and its implications for education. *Mind, Culture, and Activity, 5*(1), 25-41.

Kyrö, R., Heinonen, J., Säynäjoki, A., & Junnila, S. (2011). Occupants have little influence on the overall energy consumption in district heated apartment buildings. *Energy and Buildings, 43*, 3484-3490.

Lane, R., & Gorman-Murray, A. (2011). Tackling the 'missing scale' in environmental policy. In R. Lane, & A. Gorman-Murray, *Material geographies of household sustainability* (pp. 217-224). Farnham: Ashgate.

Lane, R., & Watson, M. (2012). Stewardship of things: the radical potential of product stewardship for re-framing responsibilities and relationships to products and materials. *Geoforum, 43*, 1254-1265.

Latour, B. (1991). Technology is society made durable. In J. Law, *A sociology of monsters: essays on power, technology and domination* (pp. 103-131). London: Routledge.

Latour, B. (1996). The trouble with actor-network theory. *Soziale Welt, 47*(4), 369-381.

Latour, B. (1999). On recalling ANT. In J. Law, & J. Hassard, *Actor network theory and after* (pp. 15-25). Oxford: Blackwell Publishers.

Latour, B. (2004). Why has critique run out of steam? From matters of fact to matters of concern. *Critical Inquiry, 30*(2), 225-248.

Latour, B. (2010). An attempt at a “Compositionist Manifesto”. *New Literary History, 41*, 471–490.

Latour, B., & Venn, C. (2002). Morality and technology. *Theory, Culture & Society, 19*(5/6), 247-260.

Laurier, E., & Philo, C. (1999). X-morphising: review essay of Bruno Latour's Aramis, or the Love of Technology. *Environment and Planning A, 31*, 1047-1071.

Laverge, J., & Janssens, A. (2012). Heat recovery ventilation operation traded off against natural and simple exhaust ventilation in Europe by primary energy factor, carbon dioxide emission, household consumer price and exergy. *Energy and Buildings, 50*, 315-323.

Lavis, J., Robertson, D., Woodside, J., McLeod, C., & Abelson, J. (2003). How can research organizations more effectively transfer research knowledge to decision makers? *The Millbank Quarterly, 81*(2), 221-248.

Law, J. (1989). Technology and heterogenous engineering: the case of Portuguese expansion. In W. Bijker, T. Hughes, & T. Pinch, *The social construction of technological systems* (pp. 111-134). London: MIT Press.

Law, J. (1991). *A sociology of monsters.* London: Routledge.

Law, J. (1991). Power, discretion and strategy. In J. Law, *A sociology of monsters: essays on power, technology and domination* (pp. 165-191). London: Routledge.

Law, J. (2004). *After method: mess in social science research.* Abingdon: Routledge.

Law, J. (2007). *Actor network theory and material semiotics.* Retrieved 2011, from www.heterogeneities.net: http://www.heterogeneities.net/publications/Law2007ANTandMaterialSemiotics.pdf

Law, J. (2008). On sociology and STS. *The Sociological Review, 56*(4), 623-649.

Law, J., & Bijker, W. (1992). Technology, stability and social theory. In W. Bijker, & J. Law, *Shaping technology/building society: studies in sociotechnical change* (pp. 290-308). London: MIT Press.

Law, J., & Callon, M. (1988). Engineering and sociology in a military aircraft project: a network analysis of technological change. *Social Problems, 35*(3), 284-297.

Law, J., & Singleton, V. (2000). Performing technology's stories: on social constructivism, performance, and performativity. *Technology & Culture, 41*(4), 765-775.

Law, J., & Singleton, V. (2013). ANT and politics: working in and on the world. *Qualitative Sociology, 36*(4), 485-502.

Law, J., & Urry, J. (2004). Enacting the social. *Economy and Society, 33*(3), 390-410.

Lawhon, M., & Murphy, J. (2012). Socio-technical regimes and sustainability transitions: insights from political ecology. *Progress in Human Geography, 36*, 354-378.

Leaman, A., & Bordass, B. (2007). Are users more tolerant of 'green' buildings? *Building Research & Information, 35*(6), 662-673.

Lee, R. (2002). Geography, policy and geographical agendas: a short intervention in a continuing debate. *Progress in Human Geography, 26*(5), 627-628.

Leggett, W. (2014). The politics of behaviour change: nudge, neoliberalism and the state. *Policy and Politics, 42*(1), 3-19.

Lennie, J. (1999). Deconstructing gendered power relations in participatory planning: towards an empowering feminist framework of participation and action. *Women's Studies International Forum, 22*(1), 97-112.

Levin, D., & Cross, R. (2004). The strength of weak ties you can trust: the mediating role of trust in effective knowledge transfer. *Management Science, 50*(11), 1477-1490.

Lewis, P. (2007). Using ANT ideas in the managing of systemic action research. *Systems Research and Behavioral Science, 24*, 589-598.

Lindsay, C. (2005). From the shadows: users as designers, producers, marketers, distributors, and technical support. In N. Oudshoorn, & T. Pinch, *How users matter: the co-construction of users and technology* (pp. 29-50). London: MIT Press.

Livingstone, S. (1992). The meaning of domestic technologies: a personal construct analysis of familial gender relations. In R. Silverstone, & E. Hirsch, *Consuming technologies: media and information in domestic spaces* (pp. 113-130). London: Routledge.

Livingstone, S. (2007). On the material and the symbolic: Silverstone's double articulation of research traditions in new media studies. *New Media & Society, 9*(1), 16-24.

Lohan, E. (1998). Review of 'Making technology our own? Domesticating technology into everyday life' by M. Lie & K. Sørensen. *Science, Technology, & Human Values, 23*(2), 249-251.

Lohan, M. (2000). Constructive tensions in feminist technology studies. *Social Studies of Science, 30*(6), 895-916.

Lohan, M. (2001). Men, masculinities and 'mundane' technologies: the domestic telephone. In E. Green, & A. Adam, *Virtual gender: technology, consumption and identity* (pp. 189-205). London: Routledge.

Lohan, M., & Faulkner, W. (2004). Masculinities and technologies: some introductory remarks. *Men and Masculinities, 6*(4), 319-329.

Lomas, K., Oreszcyn, T., Shipworth, D., Wright, A., & Summerfield, A. (2006). *Carbon Reduction in Buildings (CaRB) - understanding the social and technical factors that influence energy use in UK homes.* London: Royal Institute of Chartered Surveyors.

Lorenzoni, I., Nicholson-Cole, S., & Whitmarsh, L. (2007). Barriers perceived to engaging with climate change among the UK public and their policy implications. *Global Environmental Change, 17*, 445-459.

Lovell, H. (2004). Framing sustainable housing as a solution to climate change. *Journal of Environmental Policy & Planning, 6*(1), 35-55.

Lovell, H. (2007). Exploring the role of materials in policy change: innovation in low-energy housing in the UK. *Environment and Planning A, 39*, 2500-2517.

Lovell, H., & Smith, S. (2010). Agencement in housing markets: the case of the UK construction industry. *Geoforum, 41*, 457-468.

Lucas, K., Brooks, M., Darnton, A., & Jones, E. (2008). Promoting pro-environmental behaviour: existing evidence and policy implications. *Environmental Science & Policy, 11*, 456-466.

Maassen, A. (2009). Social science perspectives on energy transitions. *Proceedings of the Institution of Civil Engineers: Energy, 162*, 161-167.

Magnani, L., & Bardone, E. (2008). Distributed morality: externalizing ethical knowledge in technological artifacts. *Foundation Science, 13*, 99-108.

Maguire, P. (2006). Uneven ground: feminisms and action research. In P. Reason, & H. Bradbury, *The handbook of action research* (pp. 60-70). London: Sage Publications.

Mallaburn, P., & Eyre, N. (2014). Lessons from energy efficiency policy and programmes in the UK from 1973 to 2013. *Energy Efficiency, 7*, 23-41.

Manzo, L., & Brightbill, N. (2007). Towards a participatory ethics. In S. Kindon, R. Pain, & M. Kesby, *Participatory action research approaches and methods: connecting people, participation and place* (pp. 33-40). London: Routledge.

Maréchal, K. (2010). Not irrational but habitual: the importance of "behavioural lock-in" in energy consumption. *Ecological Economics, 69*, 1104-1114.

Marres, N. (2011). The costs of public involvement: everyday devices of carbon accounting and the materialization of participation. *Economy and Society, 40*(4), 510-533.

Marston, S., Jones, J., & Woodward, K. (2005). Human geography without scale. *Transactions of the Institute of British Geographers, 30*(4), 416-432.

Marti, J., & Villasante, T. (2009). Quality in action research: reflections for second-order inquiry. *Systemic Practice & Action Research, 22*, 383-396.

Martin, A. (2006). Large-group processes as action research. In P. Reason, & H. Bradbury, *The handbook of action research* (pp. 116-175). London: Sage Publications.

Martin, D. (2003). Enacting neighbourhood. *Urban Geography, 24*(5), 361-385.

Martin, R. (2002). A geography for policy, or a policy for geography? A response to Dorling and Shaw. *Progress in Human Geography, 26*, 642-644.

Marvin, S., Chappells, H., & Guy, S. (2011). Smart meters as obligatory intermediaries: reconstructing environmental action. In S. Guy, S. Marvin, W. Medd, & T. Moss, *Shaping urban infrastructures: intermediaries and the governance of socio-technical networks* (pp. 175-191). London: Earthscan.

Massey, D. (2000). Editorial: Practising political relevance. *Transactions in the Institute of British Geographers, 25*, 131-133.

Massey, D. (2001). Geography on the agenda. *Progress in Human Geography, 25*(1), 5-17.

Massey, D. (2002). Geography, policy and politics: a response to Dorling and Shaw. *Progress in Human Geography, 26*, 645-646.

Massey, D. (2008). When theory meets politics. *Antipode, 40*(3), 492-497.

Maxey, I. (1999). Beyond boundaries? Activism, academia, reflexivity and research. *Area, 31*(3), 199-208.

McCann, E., & Ward, K. (2013). A multi-disciplinary approach to policy transfer research: geographies, assemblages, mobilities and mutations. *Policy Studies, 34*(1), 2-18.

McDermont, M. (2007). Territorializing regulation: a case study of 'social housing' in England. *Law & Social Inquiry, 32*(2), 373-398.

McEvoy, D. (2001). Reducing residential carbon intensity: the new role for English local authorities. *Urban Studies, 38*(1), 7-21.

McEvoy, D., Gibbs, D., & Longhurst, J. (2001). Reducing residential carbon intensity: the new role for English local authorities. *Urban Studies, 38*(1), 7-21.

McMichael, M., & Shipworth, D. (2013). The value of social networks in the diffusion of energy-efficiency innovations in UK households. *Energy Policy, 53*, 159-168.

Mejia, F., & Kleissl, J. (2013). Soiling losses for solar photovoltaic systems in California. *Solar Energy, 95*, 357-363.

Merton Council. (2010). *The Merton Rule.* Retrieved October 18, 2010, from Merton Council: http://www.merton.gov.uk/living/planning/planningpolicy/mertonrule.htm

Milne, R. (2010). *Microgeneration permitted development move.* Retrieved December 2, 2010, from Planning Portal: http://www.planningportal.gov.uk/general/news/stories/2010/july2010/2010_07_week_3/150710_2

Misa, T. (1992). Controversy and closure in technological change: constructing "steel". In W. Bijker, & J. Law, *Shaping technology/building society: studies in sociotechnical change* (pp. 109-139). London: MIT Press.

Mitchell, T. (2009). Carbon democracy. *Economy and Society, 38*(3), 399-432.

Monni, S., & Raes, F. (2008). Multilevel climate policy: the case of the European Union, Finland and Helsinki. *Environmental Science & Policy, 11*, 743-755.

Moore, S. (2008). Promoting sustainable construction: European and British networks at the knowledge-policy interface. *Journal of Environmental Policy & Planning, 10*(3), 233-254.

Mumford, J., & Gray, D. (2010). Consumer engagement in alternative energy - can the regulators and suppliers be trusted? *Energy Policy, 38*, 2664-2671.

Murdoch, J. (1998). The spaces of actor-network theory. *Geoforum, 29*(4), 357-374.

Murphy, A. (2006). Enhancing geography's role in public debate. *Annals of the Association of American Geographers, 96*(1), 1-13.

Nässén, J., & Holmberg, J. (2009). Quantifying the rebound effects of energy efficiency improvements and energy conserving behaviour in Sweden. *Energy Efficiency, 2*(3), 221-231.

Natarajan, S., Padget, J., & Elliott, L. (2011). Modelling UK domestic energy and carbon emissions: an agent-based approach. *Energy and Buildings, 43*, 2602-2612.

Neumann, P. (2009). Political ecology: theorizing scale. *Progress in Human Geography, 33*(3), 398-406.

NHBC Foundation. (2009). *The Merton Rule: a review of the practical, environmental and economic effects.* Amersham: NHBC Foundation.

Norcliffe, G. (1977). *Inferential statistics for geographers: an introduction.* London: Hutchinson.

O'Brien, K. (2010). Responding to environmental change: a new age for human geography? *Progress in Human Geography, 35*(4), 542-549.

Ockwell, D., Whitmarsh, L., & O'Neill, S. (2009). Reorienting climate change communication for effective mitigation. *Science Communication, 30*(3), 305-327.

Ofgem. (2010). *Feed-in tariff update.* London: Ofgem.

Oikonomou, V., Becchis, F., Steg, L., & Russolillo, D. (2009). Energy saving and energy efficiency concepts for policy making. *Energy Policy, 37*, 4787-4796.

O'Riordan, T. (1999). From environmentalism to sustainability. *Scottish Geographical Journal, 115*(2), 151-165.

Ostrom, E. (2010). Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change, 20*, 550-557.

Ottinger, G. (2013). The winds of change: environmental justice in energy transitions. *Science as Culture, 22*(2), 222-229.

Paasi, A. (2004). Place and region: looking through the prism of scale. *Progress in Human Geography, 28*(4), 536-546.

Pain, R. (2004). Social geography: participatory research. *Progress in Human Geography, 28*, 652-663.

Pain, R. (2006). Social geography: seven deadly myths in policy research. *Progress in Human Geography, 30*(2), 250-259.

Pain, R. (2014). Impact: striking a blow or walking together? *ACME: An International Journal for Critical Geographies, 13*(1), 1-9.

Pain, R., Kesby, M., & Askins, K. (2011). Geographies of impact: power, participation and potential. *Area, 43*(2), 183-188.

Pain, R., Kindon, S., & Kesby, M. (2007). Participatory action research: making a difference to theory, practice & action. In S. Kindon, R. Pain, & M. Kesby, *Participatory action research approaches & methods: connecting people, participation and place* (pp. 26-32). London: Routledge.

Palm, J. (2007). District heating as a secure heat supply - a question of regulation. *Energy and Environment, 18*(6), 747-760.

Pantzar, M. (1997). Domestication of everyday life technology: dynamic views on the social history of artifacts. *Design Issues, 13*(3), 52-65.

Pantzar, M., & Shove, E. (2010). Understanding innovation in practice: a discussion of the production and re-production of Nordic Walking. *Technology Analysis & Strategic Management, 22*(4), 447-461.

Papafragkou, A., James, P., Jentsch, M., & Bahaj, A. (2010). Combined heat and power: street-level domestic microgrids. *Proceedings of the Institution of Civil Engineers - Energy, 163*, 87-89.

Park, P. (2006). Knowledge and participatory research. In P. Reason, & H. Bradbury, *The handbook of action research* (pp. 83-93). London: Sage Publications.

Parkes, M., & Panelli, R. (2001). Integrating catchment ecosystems and community health: the value of participatory action research. *Ecosystem Health, 7*(2), 85-106.

Parks, B., & Roberts, J. (2010). Climate change, social theory and justice. *Theory, Culture & Society, 27*(2-3), 134-166.

Peacock, A., Jenkins, D., Ahadzi, M., Berry, A., & Turan, S. (2008). Micro wind turbines in the UK domestic sector. *Energy and Buildings, 40*, 1324-1333.

Peck, J. (1999). Grey geography? *Transactions of the Institute of British Geographers, 24*(2), 131-135.

Peck, J. (2000). Jumping in, joining up and getting on. *Transactions of the Institute of British Geographers, 25*, 255-258.

Pehnt, M. (2008). Environmental impacts of distributed energy systems - the case of micro cogeneration. *Environmental Science & Policy, 11*, 25-37.

Peine, A., & Herrmann, A. (2012). The sources of use knowledge: towards integrating the dynamics of technology use and design in the articulation of societal challenges. *Technological Forecasting & Social Change, 79*, 1495-1512.

Pellow, D., & Brehm, H. (2013). An environmental sociology for the twenty-first century. *Annual Review of Sociology, 39*, 229-250.

Pérez-Lombard, L., Ortiz, J., González, R., & Maestre, I. (2009). A review of benchmarking, rating and labelling concepts within the framework of building energy certification schemes. *Energy and Buildings, 41*, 272-278.

Peters, H. (2003). From information to attitudes? Thoughts on the relationship between knowledge about science and technology and attitudes towards technologies. In M. Dierkes, & C. von Grote, *Between understanding and trust: the public, science and technology* (pp. 265-286). Abingdon: Routledge.

Peters, M., & Jackson, T. (2008). *Community action: a force for social change? Some conceptual observations.* Guildford: Centre for Environmental Strategy, University of Surrey.

Phelps, N., & Tewdwr-Jones, M. (2008). If geography is anything, maybe it's planning's alter ego? Reflections on policy relevance in two disciplines concerned with place and space. *Transactions of the Institute of British Geographers, 33*, 566-584.

Pickerill, J. (2014). The timeliness of impact: impacting who, when, and for whose gain? *ACME: An International Journal for Critical Geographies, 13*(1), 1-9.

Pierce, J., Strengers, Y., Sengers, P., & Bødker, S. (2013). Introduction to the Special Issue on practice-oriented approaches to sustainable HCI. *ACM Transactions on Computer-Human Interaction, 20*(4), 1-8.

Pilkington, B., Roach, R., & Perkins, J. (2011). Relative benefits of technology and occupant behaviour in moving towards a more energy efficient, sustainable housing paradigm. *Energy Policy, 39*, 4962-4970.

Pinch, N. (2005). Giving birth to new users: how the Minimoog was sold to rock and roll. In N. Oudshoorn, & T. Pinch, *How users matter: the co-construction of users and technology* (pp. 247-270). London: The MIT Press.

Pitts, A. (2008). Future proof construction - future building and systems design for energy and fuel flexibility. *Energy Policy, 36*, 4539-4543.

Planning & Climate Change Coalition. (2009). *Planning & Climate Change Coalition: position statement.* London: Town & Country Planning Association.

Pollard, J., Henry, N., Bryson, J., & Daniels, P. (2000). Shades of grey? Geographers and policy. *Transactions of the Institute of British Geographers, 25*, 243-249.

POST. (2010). *Renewable heating.* London: Parliamentary Office of Science and Technology.

POST. (2012). *Measuring energy security.* London: Parliamentary Office of Science and Technology.

POST. (2012). *Energy use behaviour change.* London: Parliamentary Office of Science and Technology.

Powells, G. (2009). *Warming homes, cooling the planet: an analysis of socio-techno-economic energy efficiency policy and practice in the UK. PhD thesis.* Durham: Durham University.

Power, E. (2009). Domestic temporalities: nature times in the house-as-home. *Geoforum, 40*, 1024-1032.

Praetorius, B., Martiskainen, M., Sauter, R., & Watson, J. (2010). Technological innovation systems for microgeneration in the UK and Germany - a functional analysis. *Technology Analysis & Strategic Management, 22*(6), 745-764.

Preda, A. (2000). Order with things? Humans, artifacts, and the sociological problem of rule-following. *Journal for the Theory of Social Behaviour, 30*(3), 269-298.

Prell, C., Hubacek, K., Quinn, C., & Reed, M. (2008). 'Who's in the network?' When stakeholders influence data analysis. *Systemic Practice & Action Research, 21*, 443-458.

Preston, I., White, V., Lloyd-Price, L., & Anderson, W. (2009). *Best practice review of community action on climate change.* Bristol: Centre for Sustainable Energy.

Pykett, J. (2012). The new maternal state: the gendered politics of governing through behaviour change. *Antipode, 44*(1), 217-238.

Pykett, J., Jones, R., Whitehead, M., Huxley, M., Strauss, K., Gill, N., . . . Newman, J. (2011). Interventions in the political geography of 'libertarian paternalism'. *Political Geography, 30*, 301-310.

Randalls, S. (2011). Broadening debates on climate change ethics: beyond carbon calculation. *The Geographical Journal*, *177,* 127-137.

Ratter, B., Philipp, K., & von Storch, H. (2012). Between hype and decline: recent trends in public perception of climate change. *Environmental Science and Policy, 18*, 3-8.

Rayner, S. (2010). Trust and the transformation of energy systems. *Energy Policy, 38*, 2617–2623.

Reason, P., & Bradbury, H. (2006). Inquiry & participation in search of a world worthy of human aspiration. In P. Reason, & H. Bradbury, *The handbook of action research* (pp. 1-14). London: Sage Publications.

Reason, P., & Bradbury, H. (2006). Preface. In P. Reason, & H. Bradbury, *The handbook of action research* (p. xxii). London: Sage Publications.

Reckwitz, A. (2002). Toward a theory of social practices: a development in culturalist theorising. *European Journal of Social Theory, 5*(2), 243-262.

Reed, M., & Bruyneel, S. (2010). Rescaling environmental governance, rethinking the state: a three-dimensional review. *Progress in Human Geography, 34*, 646-653.

Rees, W. (2009). The ecological crisis and self-delusion: implications for the building sector. *Building Research & Information, 37*(3), 300-311.

Reid, L., Sutton, P., & Hunter, C. (2009). Theorising the meso level: the household as a crucible of pro-environmental behaviour. *Progress in Human Geography, 34*(3), 309-327.

Rhodes, A. (2011). *Low carbon heat: commercial opportunities and challenges for the UK*. Retrieved from Energy Generation and Supply Knowledge Transfer Network: https://connect.innovateuk.org/web/modernbuiltktn/articles/-/blogs/6599668;jsessionid=6D8DC23E3472594A0FB80D9D

Richmond-upon-Thames Council. (2009). *Energy statement guidelines for developers.* Retrieved December 2, 2010, from Richmond-upon-Thames Council: http://www.richmond.gov.uk/energy_statement_guidelines_developers.pdf

Rijal, H. (2010). Thermal comfort in UK housing to avoid overheating: lessons from a 'Zero Carbon' case study. *Adapting to Change: New Thinking on Comfort* (pp. 1-21). London: Network for Comfort and Energy Use in Buildings.

Roberts, P. (2006). Evaluating regional sustainable development: approaches, methods and politics of analysis. *Journal of Environmental Planning and Management, 49*(4), 515-532.

Roberts, S. (2008). Demographics, energy and our homes. *Energy Policy, 36*, 4630-4632.

Rogers, E. (1995). *Diffusion of innovations* (4th ed.). New York: The Free Press.

Rommes, E., van Oost, E., & Oudshoorn, N. (2010). Gender in the design of the digital city of Amsterdam . In E. Green, & A. Adam, *Virtual gender: technology, consumption and identity* (pp. 241-261). London: Routledge.

Røpke, I. (2009). Theories of practice - new inspiration for ecological economic studies on consumption. *Ecological Economics, 68*, 2490-2497.

Rosenow, J. (2012). Energy savings obligations in the UK - a history of change. *Energy Policy, 49*, 373-382.

Rotmans, J., & Loorbach, D. (2008). Transition management: reflexive governance of societal complexity through searching, learning and experimenting. In J. van den Bergh, & F. Bruinsma, *Managing the transition to renewable energy* (pp. 15-46). Cheltenham: Edward Elgar.

Rotmans, J., Kemp, R., & van Asselt, M. (2001). More evolution than revolution: transition management in public policy. *Foresight, 3*(1), 15-31.

Rudy, A. (2005). On ANT and relational materialisms. *Capitalism Nature Socialism, 16*(4), 109-125.

Rudy, A., & Gareau, B. (2005). Actor-network theory, Marxist economics, and Marxist political ecology. *Capitalism Nature Socialism, 16*(4), 85-90.

Rutherford, J., & Coutard, O. (2014). Urban energy transitions: places, processes and politics of socio-technical change. *Urban Studies, 51*(7), 1353-1377.

Rutland, T., & Aylett, A. (2008). The work of policy: actor networks, governmentality, and local action on climate change in Portland, Oregon. *Environment and Planning D, 26*, 627-646.

Rydin, Y. (2005). Geographical knowledge and policy: the positive contribution of discourse studies. *Area, 37*(1), 73-78.

Rydin, Y. (2007). Indicators as a governmental technology? The lessons of community-based sustainability indicator projects. *Environment and Planning D, 25*, 610-624.

Rydin, Y. (2010). Actor-network theory and planning theory: a response to Boelens. *Planning Theory, 9*(3), 265-268.

Rydin, Y. (2013). The issue network of zero-carbon built environments: a quantitative and qualitative analysis. *Environmental Politics, 22*(3), 496-517.

Rydin, Y., Amjad, U., & Whitaker, M. (2007). Environmentally sustainable construction: knowledge and learning in London planning departments. *Planning Theory and Practice, 8*(3), 363-380.

Rydin, Y., Amjad, U., & Whitaker, M. (2007). Environmentally sustainable construction: knowledge and learning in London planning departments. *Planning Theory and Practice, 8*(3), 363 - 380.

Rydin, Y., Turcu, C., Guy, S., & Austin, P. (2013). Mapping the coevolution of urban energy systems: pathways of change. *Environment and Planning A, 45*, 634-649.

Ryghaug, M., & Sørensen, K. (2009). How energy efficiency fails in the building industry. *Energy Policy, 37*, 984-991.

Sandström, A. (2008). *Policy networks: the relation between structure and performance. PhD thesis*. Luleå, Sweden: Luleå University of Technology.

Sauter, R., & Watson, J. (2007). Strategies for the deployment of microgeneration: implications for social acceptance. *Energy Policy, 35*(5), 2770-2779.

Schott, J. (2001). Towards new forms of participatory technology development. *Technology Analysis & Strategic Management, 13*, 39-52.

Schreuer, A., Rohracher, H., & Späth, P. (2010). Transforming the energy system: the role of institutions, interests and ideas. *Technology Analysis & Strategic Management, 22*(6), 649-652.

Schwanen, T., & Kwan, M. (2012). Critical space-time geographies: thinking the spatiotemporal. *Environment and Planning A, 44*, 2043-2048.

Schwanen, T., Kwan, M., & Ren, F. (2008). How fixed is fixed? Gendered rigidity of space-time constraints and geographies of everyday activities. *Geoforum, 39*, 2109-2121.

Schwanen, T., Kwan, M., & Rens, F. (2014). The Internet and the gender division of labour. *The Geographical Journal, 180*(1), 52-64.

Seaman, A. (2012). *Report on the examination into Woking local development documents Core Strategy June 2011 Local Plan.* Bristol: The Planning Inspectorate.

Selwyn, N. (2003). Apart from technology: understanding people's non-use of information and communication technologies in everyday life. *Technology in Society, 25*, 99-116.

Seyfang, G., & Smith, A. (2007). Grassroots innovations for sustainable development: towards a new research and policy agenda. *Environmental Politics, 16*(4), 584–603.

Shapps, G. (2010). *The Rt Hon Grant Shapps MP - Speech given at the National House-Building Council Annual Lunch*. Retrieved December 17, 2010, from Department of Communities and Local Government: http://www.communities.gov.uk/speeches/newsroom/1783310

Sharman, A., & Holmes, J. (2010). Evidence-based policy or policy-based evidence gathering? Biofuels, the EU and the 10% target. *Environmental Policy and Governance, 20*, 309-321.

Shaw, I. (2012). Towards an evental geography. *Progress in Human Geography, 36*(5), 613-627.

Shaw, I., & Ozaki, R. (2013). Energy provision and housing development: re-thinking professional and technological relations. *Energy Policy, 60*, 427-430.

Shipworth, M., Firth, S., Gentry, M., Wright, A., Shipworth, D., & Lomas, K. (2010). Central heating thermostat settings and timing: building demographics. *Building Research & Information, 38*(1), 50-69.

Shove, E. (1998). Gaps, barriers and conceptual chasms: theories of technology transfer and energy in buildings. *Energy Policy, 26*(15), 1105-1112.

Shove, E. (2003). Converging conventions of comfort, cleanliness and convenience. *Journal of Consumer Policy, 26*, 395-418.

Shove, E. (2010). Beyond the ABC: climate change policy and theories of social change. *Environment & Planning A, 42*, 1273-1285.

Shove, E. (2011). On the difference between chalk and cheese - a response to Whitmarsh et al's comments on "Beyond the ABC: climate change policy and theories of social change". *Environment and Planning A, 43*, 262-264.

Shove, E., & Walker, G. (2007). Caution! Transitions ahead: politics, practice, and sustainable transition management. *Environment and Planning A, 39*, 763-770.

Shove, E., Chappells, H., & Lutzenhiser, L. (2009). *Comfort in a lower carbon society.* London: Routledge.

Shove, E., Watson, M., Hand, M., & Ingram, J. (2007). *The Design of Everyday Life.* Oxford: Berg.

Silverstone, R., & Hirsch, E. (1992). Introduction. In R. Silverstone, & E. Hirsch, *Consuming technologies: media and information in domestic spaces* (pp. 1-11). London: Routledge.

Skea, J. (2012). Research and evidence needs for decarbonisation in the built environment: a UK study. *Building Research & Information, 40*(4), 432-445.

Slater, T. (2012). Impacted geographers: a response to Pain, Kesby and Askins. *Area, 44*(1), 117-119.

Smith, A. (2007). Emerging in between: the multi-level governance of renewable energy in the English regions. *Energy Policy, 35*, 6266-6280.

Smith, A., Stirling, A., & Berkhout, F. (2005). The governance of sustainable socio-technical transitions. *Research Policy, 34*, 1491-1510.

Sommerville, J., & McCosh, J. (2006). Defects in new homes: an analysis of data on 1,696 new UK homes. *Structural Survey, 24*(1), 6-21.

Sørensen, K. (2004). Cultural politics of technology: combining critical and constructive interventions? *Science, Technology & Human Values, 29*(2), 184-190.

Sorrell, S. (2007). Improving the evidence base for energy policy: the role of systematic reviews. *Energy Policy, 35*, 1858-1871.

Sorrell, S., Dimitropoulos, J., & Sommerville, M. (2009). Empirical estimates of the direct rebound effect: a review. *Energy Policy, 37*, 1356-1371.

Southerton, D. (2003). 'Squeezing time': allocating practices, coordinating networks and scheduling society. *Time & Society, 12*(5), 5-25.

Sovacool, B. (2009). Scaling the policy response to climate change. *Policy & Society, 27*, 317-328.

Spaargaren, G. (2011). Theories of practices: agency, technology, and culture. *Global Environmental Change, 21*(3), 813-822.

Spataru, C., Gillott, M., & Hall, M. (2010). Domestic energy and occupancy: a novel post-occupancy evaluation study. *International Journal of Low-Carbon Technologies, 5*, 148-157.

Stafford, A. (2011). Long-term monitoring and performance of ground source heat pumps. *Building Research & Information, 39*(6), 566-573.

Star, S. (1988). The sociology of science and technology. *Social Problems, 35*(3), 197-205.

Star, S. (1991). Power, technology and the phenomenology of conventions: on being allergic to onions . In J. Law, *A sociology of monsters: essays on power, technology and domination* (pp. 26-56). London: Routledge.

Star, S. (2010). This is not a boundary object: reflections on the origin of a concept. *Science, Technology and Human Values, 35*(5), 601-617.

Star, S., & Griesemer, J. (1989). 'Translations' and boundary objects: amateurs and professionals in Berkeley's Museum of Vertebrate Zoology. *Social Studies of Science, 19*(3), 387-420.

Stedman, A., Winslow, R., & Langley, A. (2013). Micro-generation schemes: user behaviours and attitudes towards energy consumption. *Ergonomics, 56*(3), 440-450.

Stephens, J., Barton, J., & Haslett, T. (2009). Action research: its history and relationship to scientific methodology. *Systemic Practice & Action Research, 22*, 463–474.

Stevenson, F. (2009). Post-occupancy evaluation and sustainability: a review. *Proceedings of the Institute of Civil Engineers: Urban Design and Planning, 162*(DP3), 123-130.

Stevenson, F. (2010). Evaluating housing performance in relation to human behaviour: new challenges. *Building Research & Information, 38*(5), 437-441.

Stilgoe, J., Lock, S., & Wilsdon, J. (2014). Why should we promote public engagement with science? *Public Understanding of Science, 23*(1), 4-15.

Stratford, E. (1995). Gender and environment: some preliminary questions about women and water in the South Australian context. *Gender, Place & Culture, 2*(2), 209-216.

Strebel, I. (2011). The living building: towards a geography of maintenance work. *Social & Cultural Geography, 12*(3), 243-262.

Stuttaford, M., & Coe, C. (2007). Participatory learning: opportunities and challenges. In S. Kindon, R. Pain, & M. Kesby, *Participatory action research approaches & methods: connecting people, participation and place* (pp. 188-195). London: Routledge.

Suarez-Balcazar, Y., Davis, M., Ferrari, J., Nyden, P., Olson, B., Alvarez, J., . . . Toro, P. (2004). University-community partnerships: a framework and an exemplar. In L. Jason, & et al., *Participatory community research: theories and methods in action* (pp. 105-226). Washington: American Psychological Association.

Suchman, L. (2011). Anthropological relocations and the limits of design. *Annual Review of Anthropology, 40*, 1-18.

Sullivan, O. (2004). Changing gender practices within the household: a theoretical perspective. *Gender & Society, 18*(2), 207-222.

Sundblad, E., Biel, A., & Gärling, T. (2007). Cognitive and affective risk judgements related to climate change. *Journal of Environmental Psychology, 27*, 97-106.

Szerszynski, B., & Urry, J. (2010). Changing climates: Introduction. *Theory, Culture & Society, 27*(2-3), 1-8.

Szulanski, G., Cappetta, R., & Jensen, R. (2004). When and how trustworthiness matters: knowledge transfer and the moderating effect of casual ambiguity. *Organization Science, 15*(5), 600-613.

Tait, M., & Jensen, O. (2007). Travelling ideas, power and place: the cases of urban villages and business improvement districts. *International Planning Studies, 12*(2), 107-128.

Temenos, C., & McCann, E. (2013). Geography of policy mobilities. *Geography Compass, 7*(5), 344-357.

Tenner, E. (1994). *Why things bite back. Technology and the revenge of unintended consequences.* New York: A. Knopf.

Teräväinen, T. (2014). Representations of energy policy and technology in British and Finnish newspaper media: a comparative perspective. *Public Understanding of Science, 23*(3), 299-315.

Thomas, K., & Velthouse, B. (1990). Cognitive elements of empowerment: an "interpretative" model of intrinsic task motivation. *Academy of Management Review, 15*(4), 666-681.

Thompson, G. (2004). Is all the world a complex network? *Economy and Society, 33*(3), 411 - 424.

Thørgersen, J., & Ölander, F. (2003). Spillover of environment-friendly consumer behaviour. *Journal of Environmental Psychology, 23*, 225-236.

Thur, A., Furbo, S., & Shah, L. (2006). Energy savings for solar heating systems. *Solar Energy, 80*, 1463-1474.

Tuohy, P. (2009). Regulations and robust low-carbon buildings. *Building Research & Information, 37*(4), 433-445.

Turnpenny, J., & O'Riordan, T. (2007). Putting sustainability science to work: assisting the East of England Region to respond to the challenge of climate change. *Transactions of the Institute of British Geographers, 32*, 102-105.

Tweed, C. (2013). Socio-technical issues in dwelling retrofit. *Building Research & Information, 41*(5), 551-562.

UK Government. (2004). *Energy Act 2004.* London: TSO.

Urry, J. (2005). The complexities of the global. *Theory, Culture & Society, 22*(5), 235-254.

Urry, J. (2010). Consuming the planet to excess. *Theory, Culture & Society, 27*(2-3), 191-212.

van Loon, J. (2006). Network. *Theory, Culture & Society, 23*(2-3), 307-314.

Vermeylen, S. (2010). Resource rights and the evolution of renewable energy technologies. *Renewable Energy, 35*, 2399-2405.

Verplanken, B., Walker, I., Davis, A., & Jurasek, M. (2008). Context change and travel mode choice: combining the habit discontinuity and self-activation hypotheses. *Journal of Environmental Psychology, 28*, 121-127.

Vestby, G. (1996). Technologies of autonomy? Parenthood in contemporary "modern times". In M. Lie, & K. Sørensen, *Making technology our own? Domesticating technology into everyday life* (pp. 65-90). Oslo: Scandinavian University Press.

Vischer, J. (2008). Towards a user-centred theory of the built environment. *Building Research & Information, 36*(3), 231-240.

von Storch, H. (2009). Climate research and policy advice: scientific and cultural constructions of knowledge. *Environmental Science & Policy, 12*, 741-747.

Wagenaar, S., & Hulsebosch, J. (2008). From 'a meeting' to 'a learning community'. *Group Facilitation: A Research and Applications Journal, 9*, 14-35.

Wainwright, J. (2005). Politics of nature: a review of three recent works by Bruno Latour. *Capitalism Nature Socialism, 16*(1), 115-127.

Waitt, G., et al. (2012). Sustainable household capability: which households are doing the work of environmental sustainability. *Australian Geographer, 43*(1), 51-74.

Wajcman, J. (2010). Feminist theories of technology. *Cambridge Journal of Economics, 34*, 143-152.

Walker, G. (2007). Carbon reduction, 'the public' and renewable energy: engaging with socio-technical configurations. *Area, 39*(4), 458-469.

Walker, G., Cass, N., Burningham, K., & Barnett, J. (2010). Renewable energy and sociotechnical change: imagined subjectivities of 'the public' and their implications. *Environment and Planning A, 42*, 931-947.

Ward, K. (2005). Geography and public policy: a recent history of 'policy relevance'. *Progress in Human Geography, 29*(3), 310-319.

Wardale, D. (2008). A proposed model for effective facilitation. *Group Facilitation: A Research and Applications Journal, 9*, 49-51.

Warde, A. (2005). Consumption and theories of practice. *Journal of Consumer Culture, 5*(2), 131-153.

Watson, J. (2004). Co-provision in sustainable energy systems: the case of micro-generation. *Energy Policy, 32*, 1981-1990.

Wenger, E. (2000). Communities of practice and social learning systems. *Organization, 7*, 225-246.

West, C., & Zimmerman, D. (1987). Doing gender. *Gender and Society, 1*(2), 125-151.

West, J., Bailey, I., & Winter, M. (2010). Renewable energy policy and public perceptions of renewable energy: a cultural theory approach. *Energy Policy, 38*, 5739-5748.

Whatmore, S. (2006). Materialist returns: practising cultural geography in and for a more-than-human world. *Cultural Geographies, 13*, 600-609.

Whatmore, S., & Thorne, L. (1998). Wild(er)ness: reconfiguring the geographies of wildlife. *Transactions of the Institute of British Geographers, 23*(4), 435-454.

Wheelock, J. (1992). Personal computers, gender and an institutional model of the household. In R. Silverstone, & E. Hirsch, *Consuming technologies: media and information in domestic spaces* (pp. 97-112). London: Routledge.

While, A., Jonas, A., & Gibbs, D. (2010). From sustainable development to carbon control: eco-state restructuring and the politics of urban and regional development. *Transactions of the Institute of British Geographers, 35*, 76-93.

White, G., Gardner, N., & Swift, J. (2008). Carbon reduction: obligation and opportunity at regional and local levels. *Local Economy, 23*(3), 234-240.

Whitmarsh, L., & Lorenzoni, I. (2010). Perceptions, behaviour and communication of climate change. *WIRES Climate Change, 1*, 158-161.

Whitmarsh, L., & O'Neill, S. (2010). Green identity, green living? *Journal of Environmental Psychology, 30*, 305-314.

Whitmarsh, L., O'Neill, S., & Lorenzoni, I. (2011). Climate change or social change? Debate within, amongst, and beyond disciplines. *Environment and Planning A, 43*, 258-261.

Whitmarsh, L., Seyfang, G., & O'Neill, S. (2011). Public engagement with carbon and climate change: to what extent is the public 'carbon capable'? *Global Environmental Change, 21*, 56-65.

Wilhite, H. (2005). Why energy needs anthropology. *Anthropology Today, 21*(3), 1-2.

Williams, J. (2008). Green houses for the growth region. *Journal of Environmental Planning and Management, 51*(1), 107-140.

Williams, K. (2007). The extent and nature of sustainable building in England: an analysis of progress. *Planning Theory & Practice, 8*(1), 31-49.

Williamson, T., Soebarto, V., & Radford, A. (2010). Comfort and energy use in five Australian award-winning houses: regulated, measured and perceived. *Building Research & Information, 38*(5), 509-529.

Willis, K., Scarpa, R., Gilroy, R., & Hamza, N. (2011). Renewable energy adoption in an ageing population: heterogeneity in preferences for micro-generation technology adoption. *Energy Policy, 39*, 6021-6029.

Wilson, C. (2012). Up-scaling, formative phases, and learning in the historical diffusion of energy technologies. *Energy Policy, 50*, 81-94.

Wilson, C., & Chatterton, T. (2011). Multiple models to inform climate change policy: a pragmatic response to the 'beyond the ABC' debate. *Environment and Planning A, 43*, 2781-2787.

Wilson, E. (2006). Adapting to climate change at the local level: the spatial planning response. *Local Environment, 11*(6), 609-625.

Wilson, E. (2006). Developing UK spatial planning policy to respond to climate change. *Journal of Environmental Policy & Planning, 8*(1), 9-26.

Winner, L. (1999). Do artifacts have politics? In D. MacKenzie, & J. Wajcman, *The social shaping of technology* (2nd ed., pp. 28-40). Buckingham: Open University Press.

Wond, T., & Macaulay, M. (2010). Evaluating local implementation: an evidence-based approach. *Policy & Society, 29*, 161-169.

Wood, J. (2007). Synergy city: planning for a high density, super-symbiotic society. *Landscape and Urban Planning, 83*, 77-83.

Woodhouse, E., Hess, D., Breyman, S., & Martin, B. (2002). Science studies and activism: possibilities and problems for reconstructivist agendas. *Social Studies of Science, 32*(2), 297-319.

Woolgar, S., & Lezaun, J. (2013). The wrong bin bag: a turn to ontology in science and technology studies. *Social Studies of Science, 43*(2), 321-340.

Wyatt, S. (2008). Feminism, technology and the information society. *Information, Communication and Society, 11*(1), 111-130.

Yao, R., & Yu, C. (2012). Towards "zero-carbon" homes - issues of thermal comfort. *Indoor and Built Environment, 21*(4), 483-485.

Yin, R. (2009). *Case study research: design and methods* (4th ed.). London: Sage Publications.

Yohanis, Y. J. (2008). Real-life energy use in the UK: how occupancy and dwelling characteristics affect domestic electricity use. *Energy & Buildings, 40*, 1053-1059.

Yohanis, Y., Mondol, J., Wright, A., & Norton, B. (2008). Real-life energy use in the UK: how occupancy and dwelling characteristcs affect domestic electricity use. *Energy & Buildings, 40*, 1053-1059.

Zaheer, A., McEvily, B., & Perrone, V. (1998). Does trust matter? Exploring the effects of interorganizational and interpersonal trust on performance. *Organization Science, 9*(2), 141-159.

Zero Carbon Hub. (2014). *Allowable solutions and housing standards review: feedback from a series of consultation events.* London: Zero Carbon Hub.

Zuiderent-Jerak, T. (2007). Preventing implementation: exploring interventions with standardization in healthcare. *Science as Culture, 16*(3), 311-329.

Appendix 1 – The rebound effect

This appendix introduces the phenomenon known as the 'rebound effect' (Sorrell, 2009, p. 1456; Jenkins, et al., 2011; Druckman, et al., 2011)). As discussed in Section 3.4, envisaged CO_2 reductions from the use of LZC technology may not transpire due to misuse, indifference to, or rejection of the technology, for example. Another scenario is one where technologies are made use of but, in the process, the expectations of users in relation to levels of energy service provision changes. Such a phenomenon was initially observed in studies on the installation of energy efficient technologies, where these installations were found to have the potential to lead to an increase in demand for energy consuming services, thereby reducing the potential energy (and cost) savings that could be derived from actions specifically taken to improve energy efficiency (Sorrell S. , 2009). An example of a direct rebound effect is a driver who replaces a car with a fuel-efficient model, only to take advantage of its cheaper running costs to drive further and more often. An indirect rebound effect is where the cost savings derived from improved efficiency levels in one energy service, lead to more money being 'spent on other goods and services that also require energy to provide' (Sorrell S. , 2009, p. 1457).

Sorrell et al. (2009) undertook a review of studies reporting on the prevalence of direct rebound effects in households that had achieved cost savings through energy efficiency measures (such as achieving improved thermal performance of the building envelope through better insulation). The review estimated that the long-run direct rebound effect (within the OECD) for space heating was 10-30% and for other consumer energy services (such as lighting and water heating) was less than 20% (Sorrell, Dimitropoulos, & Somerville, 2009), with the effect being pronounced in low-income groups. Further research supports the association of a rebound effect with the introduction of domestic energy-efficiency measures (Nässén & Holmberg, 2009), and a wider, more recent, literature review concludes 'that direct rebound effects for end-use consumer energy services typically erode 10-30% of projected energy savings' in developed countries (Jenkins, et al., 2011, p. 27).

An extensive householder survey (encompassing mixed-age properties) also found evidence for an *envisaged* indirect rebound effect, where most participants thought that they would spend any energy cost savings achieved (such as through energy efficiency measures undertaken) on new consumer goods or holidays that would effectively diminish the CO_2 reductions attained overall (NHBC Foundation, 2012). To summarise this point, the concept of rebound effects conflicts with any assumption that domestic energy efficient technologies can be introduced without attendant implications for how household activities are undertaken (Wilhite H. , 2007).

When considering rebound effects associated with LZC technology, a distinction may be made between active adopters of such technology (that is, active retrofitters and self-builders) and passive adopters (that is, occupants of new homes, and tenants whose landlords have retrofitted LZC technology). For passive adopters, the LZC technology may form part of the reason for purchasing or renting a property but, similarly, it may not have been of importance (as explored in Chapter 6). The absence of any involvement in the technology selection process and the different levels of interest people have in reducing CO_2 emissions, saving energy costs or generating their own energy, may influence whether there is a direct rebound effect or the opposite, or whether there are any indirect rebound effects.

In Caird & Roy's (2010) UK study of retrofitted GSHP and STHW systems, some householders reported rebound effects in the form of greater hot water consumption or longer heating periods. In earlier research involving 39 STHW-retrofitted households, 21% stated that their concern over hot water consumption had decreased and 8% acknowledged that they were actually using more hot water (Caird & Roy, 2008); this research, then, provides some evidence of a rebound effect with STHW retrofitters.

A study on PV-retrofitters in Austria found evidence for a two-tier response; namely a direct rebound effect in households with a low electricity-consuming baseline, but a reduction in electricity consumption for those with a higher electricity-consuming baseline (Haas, et al., 1999). For the retrospective installation of air-to-air heat pumps in Danish homes (replacing electric heating), an average 20% rebound effect estimated for space heating was partly attributed to improved comfort levels (30% maintained higher indoor temperatures) (Gram-Hanssen, 2010) and this change was considered linked to the knowledge that heat pumps are less costly to run than direct electric heating. The introduction of a heat pump into the home also presented a latent ability to air-condition the dwellings in summer, a functionality made use of by 21% of those who knew their heat pump could be used for this purpose. This demonstrated a further rebound effect whereby additional energy-consuming activities had been catalysed by the presence of the heat pump due to its dual-functionality. This exemplifies the potentially 'catalytic properties of technology and the possibilities for change' (Lie & Sørensen, 1996, p. 13) that they may help enable.

References

Caird, S., & Roy, R. (2008). User-centred improvements to energy efficiency products and renewable energy systems. *International Journal of Innovation Management, 12*(3), 327-355.

Caird, S., & Roy, R. (2010). Adoption and use of household microgeneration heat technologies. *Low Carbon Economy, 1*, 61-70.

Druckman, A., Chitnis, M., Sorrell, S., & Jackson, T. (2011). Missing carbon reductions? Exploring rebound and backfire effects in UK households. *Energy Policy, 39*, 3572-3581.

Gram-Hanssen, K. (2010). Residential heat comfort practices: understanding users. *Building Research & Information, 38*(2), 175-186.

Haas, R., Ornetzeder, M., Hametner, K., Wroblewski, A., & Hübner, M. (1999). Socio-economic aspects of the Austrian 200 kWp-photovoltaic-rooftop programme. *Solar Energy, 66*(3), 183-191.

Jenkins, J., Nordhaus, T., & Shellenberger, M. (2011). *Energy emergence: rebound & backfire as emergent phenomena.* Oakland, USA: Breakthrough Institute.

Lie, M., & Sørensen, K. (1996). Making technology our own? Domesticating technology into everyday life. In M. Lie, & K. Sørensen, *Making technology our own? Domesticating technology into everyday life* (pp. 1-30). Oslo: Scandinavian University Press.

Nässén, J., & Holmberg, J. (2009). Quantifying the rebound effects of energy efficiency improvements and energy conserving behaviour in Sweden. *Energy Efficiency, 2*(3), 221-231.

NHBC Foundation. (2012). *Today's attitudes to low and zero carbon homes.* Milton Keynes: NHBC Foundation.

Sorrell, S. (2009). Jevons' Paradox revisited: the evidence for backfire from improved energy efficiency. *Energy Policy, 37*, 1456-1469.

Sorrell, S., Dimitropoulos, & Somerville, M. (2009). Empirical estimates of the direct rebound effect: a review. *Energy Policy, 37*, 1356-1371.

Wilhite, H. (2007). Will efficient technologies save the world? *ECEEE 2007 Summer Study* (pp. 23-30). France: ECEEE.

Appendix 2 - Action research and participatory action research

A2.1 An introduction to action research

As introduced in Section 4.4, action research is a term used to describe research which adopts an 'inquiry-in-action' approach (Reason & Bradbury, 2006a, p. xxii) as opposed to a specific methodology. Simply described, action research consists of two stages. An initial diagnostic stage involves the analysis of a selected problem and the subsequent development of a hypothesis relating to how the problem can be addressed (Barton, Stephens, & Haslett, Action research, 2009). The second stage involves the testing and refinement of the hypothesis (via repeated cycles of inquiry) in the selected research setting, constituting a real-life experiment geared at enabling change to ameliorate the selected problem (Barton, Stephens, & Haslett, Action research, 2009). This second stage clearly differentiates action research from traditional scientific research, where the prime motivation of the research is to understand a situation but not to change it. The use of the action research approach within environmental research, for example, has become more pertinent as funding agencies increasingly require research to recommend and deliver change, in addition to the traditional role of identifying problems that need addressing (Helmfrid, Haden, & Ljung, 2008). Davies & Oreszczyn (2012), for example, advocate the use of action research to assist policy makers in their efforts to decarbonise the built environment (and also to assist the planners who implement these policies). They argue that action research is an approach that can be of use in helping policy makers and planners to design, monitor, learn from and amend as necessary the decarbonisation 'experiment' that has commenced (Davies & Oreszczyn, 2012, p. 83).

In attempting to change real-life situations, which will vary across time and space, action research engages with heterogeneous 'open' systems (Barton, Stephens, & Haslett, 2009). Thus, unlike traditional scientific research, action research does not strive for the reproducibility of its results and this is not a measure of its robustness.

To deliver the change that is the focus of any action research project will require the delivery of practical outcomes of relevance to the participants. Such outcomes, for example, may be comprised of practical knowledge of use to the participants (Reason & Bradbury, 2006b) which will enable them to enact the change desired. To promote the longevity of any change, practical knowledge needs to be supplemented with a depth of understanding as to the need for the change, 'since action without reflection and understanding is blind' (Reason & Bradbury, 2006b, p. 2).

Action research is applied to situations where a change is desirable from a given perspective, such as social or environmental justice within communities (Chalmers & Colvin, 2005) or addressing practical issues within organisations (Reason & Bradbury, 2006a). In deciding what changes are desirable to promote, the person(s) instigating the research, be it ''top-down' policy research' or ''bottom-up' grassroots activist research' (Pain, 2003, p. 651), will be driven by their own values and agendas. Thus, action research is a 'strongly value-oriented' approach (Reason & Bradbury, 2006a, p. xxii) which can adopt a variety of forms. The initial stage of this research, initiated by myself, represented an element of top-down, policy-related research. The intention was for subsequent research stages to be developed in partnership with research participants, representing research more akin to the bottom-up, grassroots activist mode. However, this did not take place, as discussed in Section 5.4.

Within human geography[148], Pain (2003) identifies three forms of action research: activist, participatory and policy-related, acknowledging that these modes of research 'are not discrete but often overlap in practice' (Pain, 2003, p. 651). It was intended that this research would employ elements of each of these three modes. Firstly, the research incorporated an activist element as it was my normative goals relating to climate change that set the overall direction for the research. Secondly, participatory action research (PAR) refers to the end of the action research spectrum of approaches where the focus is on fuller active participation by those involved in the research, which was sought in this research. Thirdly, the subject matter underpinning the research was policy-relevant, pertaining to both local government policy, which may require developers to install LZC technology in new homes (Section 2.4), and central government policy, which is now focusing on distributed energy generation (Section 2.3). The use of participatory methods to establish the impact of policy implementation on 'those at the sharp end of policies' is becoming more common (Pain, 2003, p. 654) and the initial plans for this research was aligned with this approach.

A2.2 Action research approach

In order to appreciate how the action research approach differs from that of traditional scientific research, it is useful first to provide an outline of the latter. Checkland and Holwell (1998, p.10) identify the three tenets of the scientific research method as 'reductionism, repeatability and refutation'. Scientific knowledge is not an unvarying truth but an account of

[148] More specifically, within social geography (Pain, 2003)

the ‘best-tested knowledge’ which holds for today but which may be refuted tomorrow (Checkland & Holwell, 1998, p. 10). Within traditional scientific research, experimental results that are repeatable (that is, consistent over time and across space) are viewed as knowledge and hypotheses are hence put forward to provide an explanation for these observed results. Until refuted by further experiments, these hypotheses equate to current scientific knowledge. Figure A2.1 illustrates the traditional hypothesis-testing approach to traditional science.

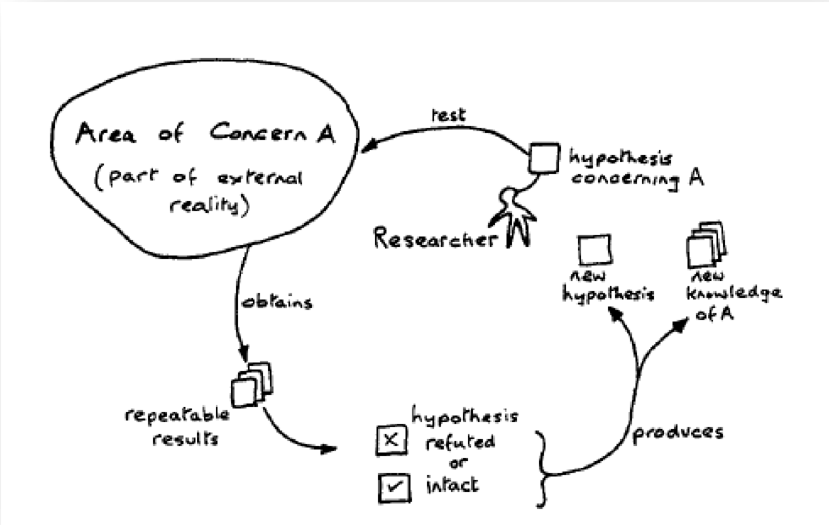

Figure A2.2: The hypothesis-testing research process of natural science (from Checkland and Holwell, 1998)

Action research, however, involves engaging with people, whose behaviours and attitudes at the individual, everyday level are likely to be unpredictable and complex. Explaining behaviours fully by reference to a closed set of variables is difficult and predicting future behaviour at the individual level cannot be exact. Given the changeable, complex nature of human behaviour (as influenced by an individual’s socio-technical relations), the traditional scientific notions of reductionism, repeatability and refutation are not deemed wholly applicable to action research (Checkland & Holwell, 1998). Instead, given action research’s focus on facilitating change, ‘the only certain object of research becomes the change process itself’ (Checkland & Holwell, 1998, p. 11).

Figure A2.2 outlines the key parts to any form of research, where a framework of linked ideas (F) are activated or applied through a methodology (M) or mix of methods. These are then used to research an area of concern (A). This way of representing research is termed the FMA model (Checkland & Holwell, 1998). When this model is applied to action research with its focus on facilitating change, it is expected that, during the research process, changes will occur to one or more of the F, M and A elements. Checkland and Holwell (1998) consider it essential to declare up front what the initial elements of F[149], M and A are to provide a baseline against which these emergent changes can be identified.

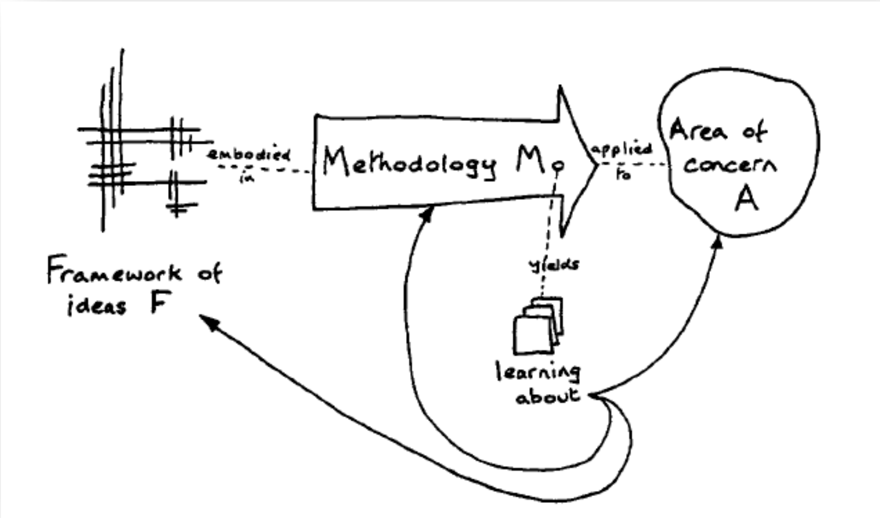

Figure A2.3: Elements relevant to any piece of research (from Checkland & Holwell, 1998)

The action research cycle is depicted in Figures A2.3 and A2.4. As evident from both diagrams, reflection on the research process is a key component and it is the repeated cycles of action and reflection that can facilitate change in line with the project's objectives. At the end of each period of action, reflection on the success of the actions undertaken enables a sound judgement to be made on the next cycle of action, incorporating any lessons learnt. This may result in a continuation or refinement of existing actions or the introduction of a new tranche of measures. In this way, action research strives for incremental and considered change.

Reflection will entail the use of the initial F and M elements to help in accounting for the existing situation, to guide the change process and to help account for the changes observed. At any stage, the researcher may consider it necessary to amend the initial F and M elements to better represent the given real-life situation. Successive appraisals of how well ideas based on the theory are enabling the project's objectives to be met can be used to refine the theory, or refine how it is being interpreted and practically applied. In this way, knowledge generated

[149] Note that more than one framework of ideas may be used at the same time within a research project (see Helmfrid, et al., 2008).

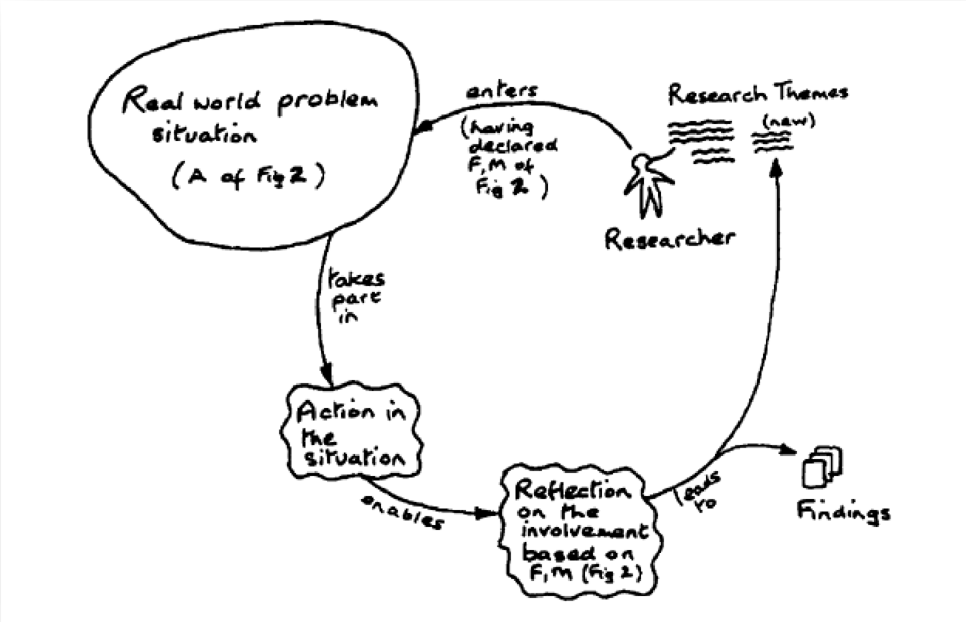

Figure A2.4: The cycle of action research in human situations (from Checkland & Holwell, 1998)

from the practical stages can be fed back into theory development and into improvements in how action research is conducted in the field (Gaventa & Cornwall, 2006).

In addition to reflection taking place during research in the field, it continues once the researcher has withdrawn from this stage, enabling the overall learning from the active research stage to be distilled and recorded (Checkland & Holwell, 1998). This point is likely to occur once the fieldwork has generated sufficient learning that meets the aims and objectives of the project[150].

In instigating change, many action researchers are exhibiting a form of activism aligned with their own values. In discussing activism versus traditional academic research, it has been proposed that activism is present to a degree in all academic activity (Pain, 2003; Cameron & Hicks, 2013) and that there is 'no inevitable conflict' between the roles of an activist and a traditional academic researcher (Pain, 2003, p. 253), a view supported by Maxey (1999). Maxey (1999) considers that the social world is a product of individuals' everyday acts: from this perspective, everything we do and think has an impact on the form the social world takes, and Maxey (1999, p.201) views activism as 'the process of reflecting and acting upon this condition'. He views every individual as an activist as each of us is 'engaged in producing the

[150] This learning may relate to any or all of the three elements: F, M and A (Checkland & Holwell, 1998).

world' (p.201). The more an individual adopts a reflexive stance on the world around them, and their existing or potential role within it, the more they can harness and direct their ability to make worthwhile changes in the social matrix. What changes are deemed worthwhile to an individual will depend on their values and intentions. In Maxey's (1999, p.201) words, 'activism means doing as much as I can from where I am'.

When attempting to make a positive change in the world aligned with their own aspirations, an action researcher is in the process trying to impose their normative goals on the research participants. In these situations, the researcher is exerting influence on the 'production of knowledge' (Kesby, 2007, p. 2816) and the direction of change. The participants, however, may not concur with the project's objectives and may seek to gain something different from the research. So long as the participants' goals for the project are broadly compatible and can be progressed towards in parallel or together, the art will be to design a flexible research trajectory that pays attention to each one of these goals and which facilitates change respective to each.

A2.3 Participatory action research

Introduction to participatory action research

Participatory action research (PAR) refers to the end of the action research spectrum of approaches where the focus is on fuller active participation by those involved in the research. By actively engaging with a varied group of participants, PAR can harness and make use of the 'many ways of knowing' (Chalmers & Colvin, 2005, p. 342) that are revealed. This notion resonates with the discussion in Section 4.2 on the merits of commencing an ANT analysis from multiple starting points.

Much of the knowledge generated may be based on qualitative experiences but also of relevance may be knowledge derived from quantitative assessments of varying aspects of the situation under study (Chalmers & Colvin, 2005). Employing both qualitative and quantitative approaches can yield 'multiple levels of analysis' (Suarez-Balcazar, et al., 2004). Whilst quantitative data can measure the outcome of people's behaviours (such as energy consumption), qualitative information derived from dialogue and narratives can assist with identifying the causes of these outcomes (Suarez-Balcazar, et al., 2004).

Table A2.2: Types of participatory research

Modes of participation	Involvement of local/researched people	Relationship of research to people
CO-OPTION	Token representatives are chosen but there is no real input or power sharing	ON
COMPLIANCE	Tasks are assigned with incentives but outsiders decide the agenda and direct the actions	FOR
CONSULTATION	Local opinions are sought but outsiders analyse and decide on the best course of action	FOR/WITH
COOPERATION	Local people work together with outsiders to determine priorities but responsibility remains with outsiders for directing the process	WITH
CO-LEARNING	Local people and outsiders share their knowledge to create new understandings and they work together to form action plans with outside facilitation	WITH/BY
COLLECTIVE ACTION	Local people set their own agenda and mobilize to carry it out in the absence of outside initiators and with or without outside facilitators	BY

(Ref: reproduced from Parkes & Panelli (2001), p.88)

Whether qualitative or quantitative, the mix of methods chosen to generate knowledge relating to a given situation should be appropriate (Pain, 2003). In this research, the majority of the knowledge generated initially will derive from a survey (qualitative questions & quantitative analysis of results) and interviews (qualitative questions).

PAR can also be characterised by the degree of participation exhibited. Table A2.1 outlines the spectrum of possible modes, distinguishing between them based on the degree of involvement of participants in, firstly, determining what the priorities are for change and, secondly, in designing and implementing action plans to deliver this change (Parkes & Panelli, 2001). As summarised by Cameron (2007, p.209):

> 'There is no single correct academic research practice; rather, it is a matter of assessing the context and working in a way that best suits the group and the circumstances, and then managing the associated challenges.'

The mode of participation adopted may affect the type and success of the outcomes generated by the PAR process (Parkes & Panelli, 2001)[151]. The intention of this research was to aim for a co-operation or co-learning mode of participation, as defined in Table A2.1. However, it was appreciated that achieving either of these modes of participation would be difficult (Cameron, 2007) (as was the case, as described in Section 5.4) because the willingness and ability of participants to fully engage with the project was uncertain.

The PAR approach: A revised FMA model

The FMA model (Figure A2.3), as proposed by Checkland & Holwell (1998) and overviewed previously in this appendix, has been further developed by Helmfrid et al. (2008) to incorporate the following aspects of PAR, as illustrated in Figure A2.4:

- the role of normative goals in research;
- the varying role of the researcher;
- the varying modes of participation of those involved in the research.

Where a researcher designs and manages the research process to specifically further a normative goal (N) within an area of concern (A), the researcher can be viewed as an actor within the process. If, however, the normative goal is associated more with the research process itself (for example, if the objective is to enable the participants to achieve their own

[151] This will in part be due to differing degrees of participant commitments to the actions decided upon (Parkes & Panelli, 2001).

goals, whatever they may be), then the researcher can be viewed as a facilitator within the process (Helmfrid, Haden, & Ljung, 2008). The role of actor and facilitator lie at two ends of a spectrum of roles which describe the part the researcher plays in relation to the type of normative goal being acted upon (Helmfrid, Haden, & Ljung, 2008). As explained in the next paragraph, I viewed myself as lying not at either end of the actor/facilitator spectrum, but adopting a hybrid position somewhere in between.

At the personal level, I hold a strong normative goal in relation to acting on my concerns regarding climate change. At the level of the research project, this concern translated into the goal of helping to promote the optimal use of LZC technology such that the potential reductions in domestic CO_2 emissions can be achieved. However, I did not hold specific detailed objectives relating to what improvements were necessary and how they should be enacted. Instead, ideas for change were to be generated from an evaluation of the existing situation as related by the participants' shared experiences through the questionnaire survey (Phase 1 of the research, see Section 5.3), interviews (Phase 2) and follow-on interactions (Phase 3). The aim was for participants to be involved in this evaluation and therefore their own normative goals would have determined the changes to be promoted. Where participants exhibit a varied set of normative goals, Helmfrid et al. (2008) do not consider this to be necessarily a problem as long as enough consideration is given to accommodating any differences.

In Figure A2.4, Helmfrid et al. (2008) distinguish between what they term interactive action research and extractive action research. Within the former, there are joint reflective stages between participants and researcher (entitled collaborative learning), which are an integral part of PAR modes that specifically promote learning by the participant (as in the 'co-learning' mode summarised in Table A2.1, for example). Within extractive action research, the reflective stages are not held with the participants but within the academic community and thus 'the main flow of information is from the participants to the academic community' (Helmfrid, Haden, & Ljung, 2008, p. 120) (as in the 'compliance' mode summarised in Table A2.1, for example). Chiu (2006, p.188) advocates that the reflective stage should include considerations of the 'interactions between the researcher and the participants' as this 'is likely to illuminate how changes occur.' This resonates with the discussion on ANT in Section 4.2, where the key role of the researcher was also highlighted (Ruming, 2009).

In certain situations, existing communities identify issues that need resolving and perceive the need for an action research approach, leading to the enrolment of a researcher to facilitate the research (Helmfrid, Haden, & Ljung, 2008). The researcher, thus engaged, acts as a form of consultant. This situation contrasts with those researchers who perceive the need for the research based on their own experience or knowledge and subsequently conduct a field study within a selected community (Helmfrid, Haden, & Ljung, 2008).

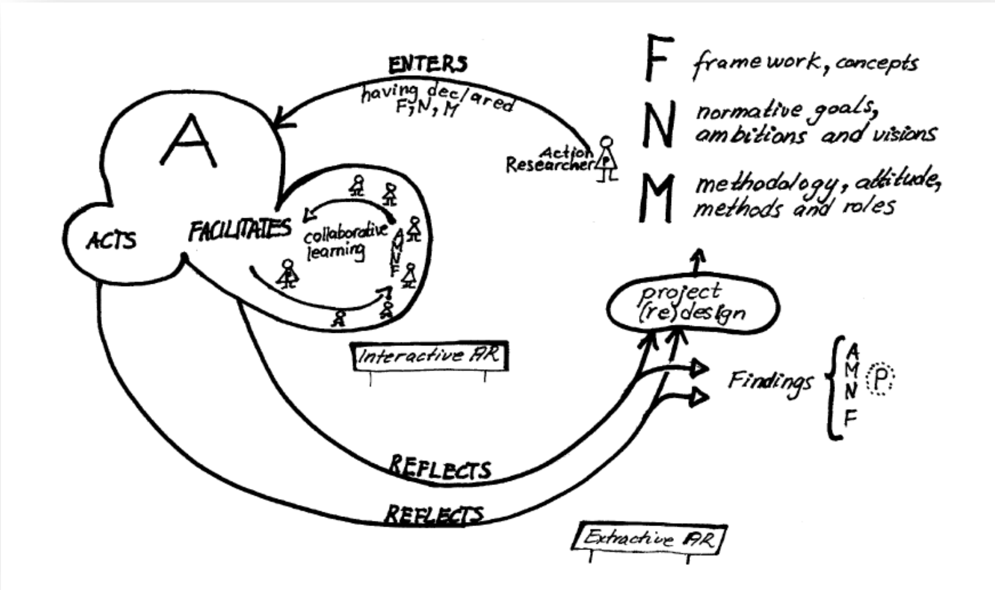

Figure A2.4: FMA model amended to incorporate normative goals (N), process competence (P) and interactive/extractive approaches (from Helmfrid et al., 2008)

This research is in line with the field study approach, as the need for the research emanates from my own reading of the relevant literature. However, before commencing on the PAR phase of the research, householders with LZC technologies were surveyed and interviewed. The information thus extracted was fed back to the research participants at the onset of the intended PAR stage, providing a summary of the existing situation which was to help form the basis for initial joint reflection. The use of a traditional research method (in the form of a questionnaire and interviews) to help inform the early stages of the PAR process, including the refinement of the framework of ideas used to guide the research, is illustrated by the outer loop in Figure A2.5 (Helmfrid, Haden, & Ljung, 2008).

Researcher as facilitator of the PAR process

As a facilitator for the collaborative learning that takes place within a PAR approach, the researcher should ensure that they are sufficiently prepared for this task. This preparedness will result partly from a sound knowledge of the subject that forms the focus of the research, but will also be dependent on the level of skills the researcher has in facilitating change. Helmfrid et al. (2008, p.121) have used the term 'process competence' to encapsulate the researcher's ability in this regard (refer to Figure A2.5 where process competence is denoted by 'P' within the figurine of the researcher).

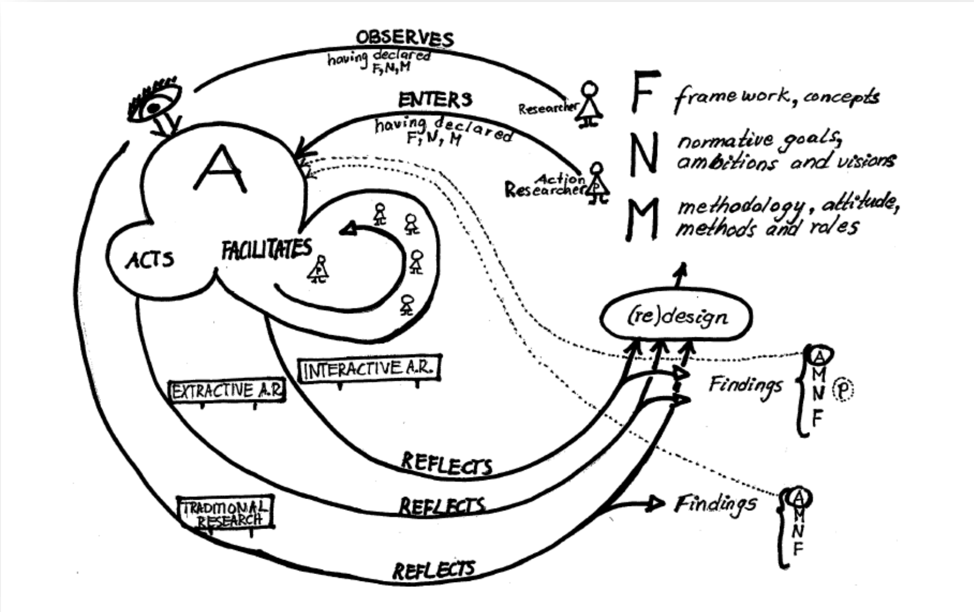

Figure A2.5: The complete model, with the addition of traditional scientific research (from Helmfrid et al., 2008)

The initial stage of PAR involves the sharing of experiences and discussions that relate to the area of concern. Techniques that may assist participants in bringing forth relevant information include one-to-one interviews and less structured dialogue, learning histories (see Reason, et al., 2010), timelines (Pain, 2004), diaries and photographs. Within the reflexive stages, group-based interactions may dominate (as in general meetings and focus groups). In this research, the selection of techniques to be used was left flexible and was to be determined in part by the number of householders interested in participating, but key techniques were considered to be interviews and group meetings.

Characterising the community

In characterising the community at whom the research project was targeted, it should be noted that the term 'community' has 'numerous sociological and non-sociological meanings' (Peters & Jackson, 2008, p. 5). For example, a community can be comprised of individuals who have something in common, such as an ideology (Seyfang & Smith, 2007), types of work, activities or ownership of specific items, or who share a geographical identity (Peters & Jackson, 2008). The former are often referred to as 'communities of interest' and the latter as 'communities of place' (Peters & Jackson, 2008, p. 5). In defining the parameters that will set the boundary for the community, it is necessary to identify what distinguishes the intended target group from others (Peters & Jackson, 2008), ensuring that the target group selected is compatible with the overall research objectives set.

The community that is the target group for this research is a sub-set created by the overlap between a wider community of place (i.e. those residing in the borough of Woking) and a community of interest (i.e. those with LZC technology installed at time of their home's construction in and after 2006). This delineation of the target research group excludes those who have actively and voluntarily retrofitted their homes with LZC technology. Such households have exhibited clear pro-environmental behaviour (whether driven by economic or environmental reasons), whereas those moving into homes with such technologies already installed would be expected to be more representative of the wider population.

It was not expected that those households that made up the target group (representing developments across the selected borough) would have extensive social ties to each other, although a degree of association between neighbours within any given development was expected. One of the research objectives was to connect up these potential members, thus helping to create the community as previously defined. The emergence of a community relies in part upon the creation of new relationships between people and between people and non-human forms (Reason, et al., 2010), such as the meeting places and sources of information used. The community may also experience changes in existing relationships (such as that between householders and their LZC technology).

Using the notion that our identities are 'relational and performative' (Maxey I. , 1999), the participation of individuals in PAR will impact on their self-identities and how others identify with them. PAR can be viewed, then, as a vehicle for destabilising aspects of existing identities and for helping to influence the direction in which these aspects of identity re-stabilise. In recognising that the world is the product of a 'continuous process of co-creation' (Reason, et al., 2010, p. 97), the PAR process helps shape this continuous process through the emergence of new connections.

The creation of new and altered relationships may impact on an individual's ability and drive to make changes in their everyday lives. Whether this development in the individual can be ascribed to knowledge gained, changes in social and personal norms (see Peters & Jackson, 2008) or in a heightened belief in the efficacy of their own actions, for example, the result may be the empowerment of the PAR participant. This link between 'empowerment and relational processes' (Maguire, 2006, p. 64) is one made by a number of researchers in the field of PAR (such as Kesby, 2007).

A2.4 Selection of theory/framework of ideas

There are a range of viewpoints as to how theory should guide action research and Dick et al. (2009) outline how it can do so in two ways. Firstly, they refer to 'content theory' which enables 'participants to clarify and describe the dynamics of the issues that are the focus of their research' and secondly 'methodological theory' which enable 'participants to stengthen their processes of inquiry' (Dick, Stringer, & Huxham, 2009, p. 8). In this research, ANT and domestication theory (discussed in Sections 4.2 and 4.3 respectively) were the selected approaches used to:

- help formulate the initial questionnaire and interview questions;
- structure and assist with the analysis of the research data obtained; and, potentially,
- help guide appropriate interventions to improve LZC technology-householder relations.

In terms of content theory and methodological theory, domestication theory might possibly be described more as the former with ANT more aligned with the latter description.

A2.5 Summary

This appendix has provided an account of the action research approach and has set out how this mode of research was to be applied in the context of this study. Chapter 5 details the practical aspects of how the research was actually conducted and provides an account of the determining factors that contributed to the shaping of the research trajectory in practice.

References

Barton, J., Stephens, J., & Haslett, T. (2009). Action research. *Systemic Practice & Action Research, 22*, 475-488.

Cameron, J. (2007). Linking participatory research to action: institutional challenges. In S. Kindon, R. Pain, & M. Kesby, *Participatory action research approaches & methods: connecting people, participation and place* (pp. 205-215). London: Routledge.

Cameron, J., & Hicks, J. (2013). Performative research for a climate politics of hope. *Antipode, on-line, doi:10.1111/anti.12035*, 1-19.

Chalmers, H., & Colvin, J. (2005). Addressing environmental inequalities in UK policy: an action research perspective. *Local Environment, 10*(4), 333-360.

Checkland, P., & Holwell, S. (1998). Action research: its nature and validity. *Systemic Practice and Action Research, 11*(1), 9-21.

Davies, M., & Oreszczyn, T. (2012). The unintended consequences of decarbonising the built environment. *Energy and Buildings, 46*, 80-85.

Dick, B., Stringer, E., & Huxham, C. (2009). Theory in action research. *Action Research, 7*(1), 5-12.

Gaventa, J., & Cornwall, A. (2006). Power and knowledge. In P. Reason, & H. Bradbury, *The handbook of action research* (pp. 71-82). London: Sage Publications.

Helmfrid, H., Haden, A., & Ljung, M. (2008). The role of action research in environmental research. *Systemic Practice & Action Research, 21*, 105-131.

Kesby, M. (2007). Spatialising participatory approaches: the contribution of geography to a mature debate. *Environment and Planning A, 39*, 2813-2831.

Maguire, P. (2006). Uneven ground: feminisms and action research. In P. Reason, & H. Bradbury, *The handbook of action research* (pp. 60-70). London: Sage Publications.

Maxey, I. (1999). Beyond boundaries? Activism, academia, reflexivity and research. *Area, 31*(3), 199-208.

Pain, R. (2003). Social geography: on action-orientated research. *Progress in Human Geography, 27*(5), 649-657.

Pain, R. (2004). Social geography: participatory research. *Progress in Human Geography, 28*, 652-663.

Parkes, M., & Panelli, R. (2001). Integrating catchment ecosystems and community health: the value of participatory action research. *Ecosystem Health, 7*(2), 85-106.

Peters, M., & Jackson, T. (2008). *Community action: a force for social change? Some conceptual observations.* Guildford: Centre for Environmental Strategy, University of Surrey.

Reason, P., & Bradbury, H. (2006a). Preface. In P. Reason, & H. Bradbury, *The handbook of action research* (p. xxii). London: Sage Publications.

Reason, P., & Bradbury, H. (2006b). Inquiry & participation in search of a world worthy of human aspiration. In P. Reason, & H. Bradbury, *The handbook of action research* (pp. 1-14). London: Sage Publications.

Reason, P., Coleman, G., Ballard, D., Williams, M., Gearty, M., Bond, C., & Seeley, C. (2010). *Insider voices: human dimensions of low carbon technology.* Bath: Centre for Action Research, University of Bath.

Ruming, K. (2009). Following the actors: mobilising an actor-network methodology in geography. *Australian Geographer, 40*(4), 451-469.

Seyfang, G., & Smith, A. (2007). Grassroots innovations for sustainable development: towards a new research and policy agenda. *Environmental Politics, 16*(4), 584-603.

Suarez-Balcazar, Y., Davis, M., Ferrari, J., Nyden, P., Olson, B., Alvarez, J., . . . Toro, P. (2004). University-community partnerships: a framework and an exemplar. In L. Jason, & et al., *Participatory community research: theories and methods in action* (pp. 105-226). Washington: American Psychological Association.

Appendix 3 – Variation in sustainable energy targets applied to new developments

In 2011, as mentioned in Section 5.3, the scale of the housing development at which any sustainable energy target became applicable varied between planning authorities within Berkshire and Surrey in the following ways:

- certain planning authorities applied the target to all domestic developments, from one building unit and above:
    - e.g. Runnymede Borough Council, Woking Borough Council;
- certain planning authorities applied the target only when a specified minimum number of houses were built as part of a development:
    - e.g. Reading Borough Council's threshold was 10 dwellings whilst that at Surrey Heath Borough Council was 5 dwellings;
- certain authorities had different tiers of targets that applied to different scales of development (based on the number of units or total floor space)
    - e.g. At Bracknell Forest Council, Tier 1 applied to 1 to 4 dwellings and was comprised of a 10% target relating to predicted energy requirements; there was no CO_2 reduction target. Tier 2 applied to developments of 5 or more dwellings or a total floor area greater than 500 m^2; the target was comprised of both a 10% reduction target in CO_2 emissions and a 20% target with respect to predicted energy requirements.

Clearly, the proportion of new housing that needed to comply with sustainable energy targets varied between authorities. Research on what factors caused the observed variance in this type of policy appears absent from the academic literature. Sovacool et al. (2009, p.320) comment that 'decentralising environmental decision making to local communities provides for inter-jurisdictional competition that can maximise environmental policy.' This idea raises the question of whether certain local authorities (who applied the target to *all* new dwellings at the onset) had wanted to gain recognition for their stringent approach.

References

Sovacool, B. (2009). Scaling the policy response to climate change. *Policy & Society, 27*, 317-328.

Appendix 4 - Survey questionnaire   Research into Low and Zero Carbon (LZC) Energy Technologies in the Home

I would really appreciate it if an adult in your household could take 5 minutes to complete this voluntary questionnaire. I am a student at Royal Holloway, University of London and am conducting research on low and zero carbon (LZC) energy technologies installed in homes within the Woking area. These energy technologies include photovoltaic (PV) panels, solar thermal systems, air source heat pumps and district heating systems, for example. This questionnaire forms the first phase of a research project which is exploring how LZC energy technologies influence the behaviour of householders and to what extent the performance of these technologies is maximised. Please return the completed questionnaire using the envelope provided. All information received will be treated in the strictest confidence and will only be used for my research purposes. You may leave out questions you do not want to answer. If you have any questions relating to the completion of this questionnaire, please contact me by e-mail at: lise.andreassen.2010@live.rhul.ac.uk.

A. General Information

1. What type of LZC energy technology provides your home with energy (as installed directly in your home or in an apartment building, for example)?

- ○ solar PV panels (→ electricity)
- ○ solar thermal panels (→ hot water)
- ○ biomass boiler
- ○ mechanical ventilation with heat recovery
- ○ ground source heat pump
- ○ wood-burning stove
- ○ micro-combined heat and power (μ-CHP)
- ○ district/communal heating systems
- ○ wind turbine
- ○ air source heat pump
- ○ and/or another LZC technology (please specify) ....

2. Who, in the house, ensures that the LZC energy technology is operating efficiently and is maintained as necessary?..

3. Who has the main responsibility for making sure that day-to-day practices in the home make the most of the energy produced?..

B. Which sources of information do you use to help you maximise the performance of and benefits from your LZC energy technology? (Tick one box per row)	***Please indicate frequency of use for each information source*** ***Never***	***Occasionally (Up to 2 times/yr)***	***Regularly (3 to 4 times/yr)***	***Frequently (5 + times/yr)***
- manufacturer's instruction manual	☐	☐	☐	☐
- manufacturer's helpline (via telephone, e-mail or website)	☐	☐	☐	☐
- developer's/Housing Association's/Council's/landlord's home user guide	☐	☐	☐	☐
- installer or maintenance company	☐	☐	☐	☐
- internet (please specify websites:..)	☐	☐	☐	☐
- members of your household (who? ....)	☐	☐	☐	☐
- a local environmental network or advisor (which? ....)	☐	☐	☐	☐
- neighbours/other households with similar LZC energy technology installed	☐	☐	☐	☐
- other sources of information (please specify: ....)	☐	☐	☐	☐

[1/1]

C. Please indicate how much you agree or disagree with the following statements (tick one box per row):	*Strongly agree*	*Agree*	*Neither agree or disagree*	*Disagree*	*Strongly disagree*
1. The presence of the LZC energy technology was a positive influence on your choice to live in your home (whether buying or renting).	☐	☐	☐	☐	☐
2. You are interested in the ways in which your LZC energy technology works and what affects its performance level.	☐	☐	☐	☐	☐
3. The developer or landlord has provided you with sufficient information on operating and maintaining your LZC energy technology.	☐	☐	☐	☐	☐
4. You understand how your household practices may impact on the benefits gained from your LZC energy technology.	☐	☐	☐	☐	☐
5. You are satisfied with the performance of your LZC energy technology.	☐	☐	☐	☐	☐
6. Seeing your LZC energy technology has led to others installing similar technology.	☐	☐	☐	☐	☐
7. The presence of your LZC energy technology has caused you to do things	☐	☐	☐	☐	☐

differently **inside** your home (e.g. changes to routines relating to electricity, heating or hot water consumption).If so, please give some specific examples:

....

8. The presence of your LZC energy technology has led you to behaving differently	☐	☐	☐	☐	☐

away from your home due to an increased environmental awareness (e.g. changes to shopping habits or car usage). If so, please give examples:

....

9. The presence of your LZC energy technology has led you to get involved with new	☐	☐	☐	☐	☐

activities **outside of** the home or new people (e.g. talking with people about the technologies, joining new groups). If so, please give some examples:

....

[2/1]

D. How significant have the following <u>incentives</u> been for improving the performance of your LZC energy technology? (Tick one box per row)	***Extremely significant***	***Very significant***	***Somewhat significant***	***Not very significant***	***Not at all significant***
- reducing energy costs	☐	☐	☐	☐	☐
- reducing carbon dioxide emissions (and helping to combat climate change)	☐	☐	☐	☐	☐
- producing more of your own energy (i.e. promoting self-sufficiency)	☐	☐	☐	☐	☐
- reducing demands on non-renewable fossil fuels (i.e. oil, natural gas, coal)	☐	☐	☐	☐	☐
- pleasing particular household members (if so, who?...)	☐	☐	☐	☐	☐
- demonstrating success to others **outside** of your household (who?.........................)	☐	☐	☐	☐	☐
- interacting with and gaining feedback from display monitors and meters	☐	☐	☐	☐	☐
- other incentives (please specify: ....)	☐	☐	☐	☐	☐

E. Please indicate the significance of the following potential <u>obstacles</u> to improving the performance of your LZC technology? (Tick one box per row)	***Extremely significant***	***Very significant***	***Somewhat significant***	***Not very significant***	***Not at all significant***
- an insufficient understanding of the best operating and maintenance procedures to follow for the LZC energy technology	☐	☐	☐	☐	☐
- the time and effort needed to find out how best to operate and maintain the LZC energy technology	☐	☐	☐	☐	☐
- insufficient time/ability to assess and monitor the technology's performance levels	☐	☐	☐	☐	☐
- your personal routines/habits within the home that you **do not want** to change	☐	☐	☐	☐	☐
- your personal routines/habits within the home that you **want to** change	☐	☐	☐	☐	☐
- the routines, habits and attitudes of other members of your household	☐	☐	☐	☐	☐
- the inaccessibility of component parts of the LZC technology for maintenance etc.	☐	☐	☐	☐	☐
- a lack of interest in the cost of energy	☐	☐	☐	☐	☐

(cont.) E. Please indicate the significance of the following potential <u>obstacles</u> to improving the performance of your LZC technology?	*Extremely significant*	*Very significant*	*Somewhat significant*	*Not very significant*	*Not at all significant*
- the 'invisibility' of the LZC energy technology within the home	☐	☐	☐	☐	☐
- insufficient opportunity to discuss your LZC energy technology with other owners	☐	☐	☐	☐	☐
- an insufficient interest in climate change or the depletion of non-renewable fossil fuels (i.e. oil, natural gas, coal)	☐	☐	☐	☐	☐
- you consider that your contribution to addressing these environmental concerns would be too insignificant to bother about	☐	☐	☐	☐	☐
- other obstacles (please specify: ....)	☐	☐	☐	☐	☐

E. So that I can analyse the data you have provided, please could you also provide the following personal information:

1. Background information on you: Gender: ○ Female ○ Male

Age: ○ 18 - 25 ○ 26-35 ○ 36-45 ○ 46-55 ○ 56-65 ○ 66+

2. Please tell me about the number of people living in your household:

Number of adults (including yourself): 1 ○ 2 ○ 3 ○ 4 ○ Number of children aged under 10: 1 ○ 2 ○ 3 ○ 4 ○

Number of children aged 10 - 18: 1 ○ 2 ○ 3 ○ 4 ○

3. *Combined household income*: ○ below £20,000 ○ £20,000 - £40,000 ○ £40,000 - £60,000 ○ above £60,000

4. Is your home:
○ owner-occupied (and designed by a developer) ○ a housing association house or flat (rented)
○ owner-occupied (and designed by yourself) ○ a house or flat rented from the Council
○ a housing association house or flat (shared ownership) ○ privately rented ○ other

5. Is your home:
○ terraced ○ a flat or maisonette
○ semi-detached ○ detached

[4/1]

6. How many bedrooms are there in your home? ☐ *7. How long have you lived in this home?* ☐ years

8. If you are a tenant, what is the length of your tenancy agreement? ☐ months, or ☐ years, or ☐ tick box if a secure tenant

9. *If you are a member of a residents' association, please give its name:* ....

Further research:

Once I have analysed the returned questionnaires, I would very much like to interview householders to obtain a selection of more detailed accounts of experiences with LZC energy technologies. The aim of the following stage of the project is to initiate a local network of LZC energy technology users in the Woking borough. Members of this network will be able to exchange information and experiences in relation to their installed technologies, and will be able collectively to decide what aims the network should have (e.g. as a social network, the provision of training, assistance with trouble-shooting).

Would you like to be kept informed of the development of this local network?	**Yes / No**	(please circle your answer)
Would you be willing to be interviewed as part of this research project?	**Yes / No**	(please circle your answer)
Would you like to hear about the results of the research?	**Yes / No**	(please circle your answer)

Any additional comments you would like to make in relation to your installed LZC energy technology (please also use back page if needed):

____

____

Your contact information (please complete this to hear about the research results, the development of the local network or if willing to be interviewed):

Name: ____________________ Address: ____________________

E-mail address: ____________________ ____________________

Date: ________ Tel. No. ____________________ __________ Post code: __________

Thank you for taking part in this research. Please return the completed questionnaire in the FREEPOST envelope provided (no stamp is required), preferably before 30th January 2012.

Should you mislay the FREEPOST envelope, please return the completed questionnaire to:

Freepost RSTC-JUJA-JLKJ
Lise Andreassen
Department of Geography
Royal Holloway University of London
Egham Hill
EGHAM
TW20 0EX

This survey has been undertaken using information supplied by Woking Borough Council.

V6

Appendix 5 – The acquiescence response set

The survey responses for Section C of the questionnaire have been collated in Figure A5.1 to help determine whether there is evidence of the 'acquiescence response set' (Converse & Presser, 1986, p. 38) as introduced previously in Section 5.3. For five of the Section C statements, the peak response is 'Agree', whilst that for the remaining four is either 'Neither agree or disagree' or 'Disagree'. Given the spread of the peak responses and the variable shape of the response set for the nine questions, it is not considered there is any clear evidence of any 'acquiesence response set' influencing the questionnaire results, nor any propensity for participants to avoid answering the question by selecting the 'Neither agree or disagree' option (Fink, 1995).

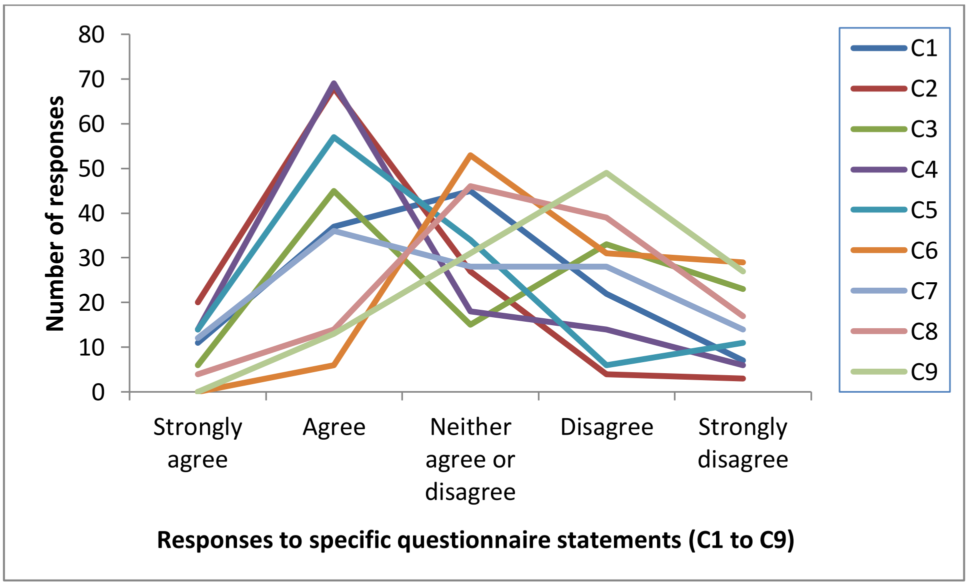

Figure A5.1. Responses to specific questionnaire statements (Section C: C1 to C9)

References

Converse, J. & Presser, S., 1986. *Survey questions.* London: Sage Publications.

Fink, A., 1995. *How to ask survey questions.* London: Sage Publications.

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Appendix 6 – Covering letter for questionnaire survey

Dear Sir/Madam 21st January 2012

I am a PhD student at Royal Holloway, University of London, conducting research on low carbon and renewable energy technologies within the Woking area. These energy technologies include photovoltaic panels, solar thermal panels, air source heat pumps, combined heat & power and district heating systems. I understand that your home is installed with one or more of these technologies (or that they serve communal areas of your development). I would really appreciate it if an adult in your household could take 5 minutes to complete and return the attached voluntary questionnaire, in the Freepost envelope provided. Should the questionnaire not apply to you, could you please still return the questionnaire, stating this, so I can update my records.

All information received will be treated in the strictest confidence and will only be used for my research purposes.

Given the Government's policy of achieving 'zero-carbon' new homes by 2016, the extent to which low carbon and renewable energy technologies are designed into new homes is set to increase significantly. So it is especially important to learn *now* from the experiences of existing users of these technologies, such as yourself. Overall, this research will investigate:

- how such technologies are used in practice and what experiences occupants have regarding these new forms of technology;
- whether these low carbon and renewable energy technologies are likely to deliver the carbon dioxide reductions envisaged; and
- how the design/installation/use of these energy technologies can be improved.

Relevant research results will be communicated to local planners, developers, housing associations, architects and technology manufacturers and installers. Your valuable input to this research will therefore be made good use of. For those interested, there is the opportunity for further involvement in the research through interviews and participation in a local network of householders who use low carbon and renewable energy technologies.

Many thanks in advance for completing and returning the questionnaire.

Regards

Lise Andreassen
(lise.andreassen.2010@live.rhul.ac.uk)

Appendix 7 – Interview topics (tailored)

Optimising low to zero carbon technologies in new homes

Interview between Lise Andreassen and XXX & partner (have PV & STHW systems)

Date: 3.30pm on Saturday, 25th February Venue: XXX, Woking

<u>**Interview topics**</u>

1. **How has the use of the solar thermal/PV technology been incorporated into your daily routines?**
2. **What feedback information on the performance of the solar thermal/PV technology is available to you?**
3. **What degree of control do you feel you have over the solar thermal/PV technology?**
4. **Is maintenance/servicing of the solar thermal/PV technology carried out in accordance with the manufacturer's instructions or other source of information?**
5. **What is the level and distribution of involvement amongst household members?**
6. **Has the presence of the solar thermal/PV energy technology resulted in you being perceived differently by others (e.g. as a trusted source of information on the technology)?**
7. **Has the presence of the solar thermal/PV energy technology in the home caused you to behave or think differently to before?**
8. **What degree of communication in the home is there concerning the technology?**
9. **What structural aspects in the home, & interactions with other items, influence the way in which the solar thermal/PV technology is used?**
10. **Has any organisation proactively made contact with you in relation to your solar thermal/PV technology (e.g. maintenance companies)?**
11. **How is the solar thermal/PV technology perceived?**

12. Technology specific details.

13. Would you appreciate assistance/ information/ training/ support in relation to your solar thermal/PV technology?

Appendix 8 – Interview questions (tailored)

Interview questions – Tailored for XXX

Signing consent form/refreshments (3.30pm)

1. **How has the use of the solar thermal/PV technology been incorporated into your daily routines?** (3.35pm)
   - What steps did you take to initially integrate the technology into your household routines?
   - What new routines and habits has the technology led to? What were the steps involved in this?
     - *any evidence of load shifting? (matching up demand profile with generation profile) – if so, how was this brought about?*
     - *are appliances cold fill?*
       - *Is incentive to make use of generated electricity? What is the difference between p/kWh for imported, exported & generated electricity? Do they benefit from the FIT?*
       - *Any change in times of showers/baths?*
   - How much of what you do in relation to the LZC technology has become habit, and how much is still consciously thought out?
   - What seasonal variations are there in your behaviour/routines in relation to the LZC technology?

2. **What feedback information on the performance of the solar thermal/PV technology is available to you (e.g. via meters/monitors)?** (3.40pm)
   - In which room or space is the meter/monitor located?
   - Is this an accessible, well-used location?
   - How often is the meter/monitor checked?
   - Do you intentionally seek out the monitor or look in passing?
   - How evident is it that the LZC technology is switched on and working effectively? (e.g. trickling noise)
   - Has any evaluation of the LZC technology been carried out by the housing developer or Council (e.g. building inspector)?
   - Are there any improvements in the feedback of information that you would like to see?

3. **What degree of control do you feel you have over the LZC technology?** (3.45pm)
    - Where is the LZC technology and associated equipment located?
    - Do the available controls (e.g. timers) help you to optimise the technology? E.g. are they accessible and easy to use? Possibly optimise indirectly via controls on gas boiler.
    - Do you follow the guidance on operating the LZC technology as given within the user manual or other source of information? – ***Ask to complete page 1 of questionnaire***
    - Have you made any changes to the LZC energy technology and ancillary equipment?
    - Have you set yourself any goals with respect to your LZC energy technology?
    - Have there been any evident changes to the incentives and obstacles to improving the existing levels of performance of the LZC technology since moving into the home?
    - How satisfied are you with your LZC energy technology?
    - Are there any inconveniences experienced as a result of the technology?
    - How could your degree of control over the technology be improved (realistically and ideally)?

4. **Is maintenance/servicing of the LZC technology carried out in accordance with the manufacturer's instructions or other source of information?** (3.50pm)
    - W.r.t. frequency and scope?
    - Who carries out the maintenance/servicing?
    - Have you got the following information:
        - key contacts and information sources *(Will the contacts change after the defects or warranty period has expired? - What is the warranty period? Have useful relationships been developed?)*
        - maintenance and servicing requirements and schedules
        - troubleshooting guides and procedures
    - Have required maintenance tasks been:
        - demonstrated to you (e.g. by the developer)?
        - outlined in the home user guide or other source of information?
    - What have been the costs of maintenance compared to conventional heating/hot water/electricity systems *Q - Only been in the house for 3 months – have there been any maintenance issues to date?*

- Are there any improvements you would like to see in how servicing and maintenance activities are arranged?

5. **What is the level and distribution of involvement amongst household members?** (3.55pm)
   - Has the assignment of roles with respect to operating and maintaining the LZC technology changed since occupying the home?
   - How are household members influenced to behave in a desired manner w.r.t. the LZC technology?
     - consider the decision making process & influence of household members
     - look at the type of influencing used
     - how consistent is the behaviour in relation to LZC technologies within the household?
     - assess level of engagement with technology & motivation to optimise the technology

6. **Has the presence of the LZC energy technology resulted in you being perceived differently by others (e.g. as a trusted source of information on the technology)?** (4.00pm)
   - Has the technology been discussed with friends, family, neighbours & work colleagues?
   - Have you provided advice to others in relation to the technology?
   - Is there any evidence of influencing others to install LZC technologies?
   - Has the presence of the LZC technologies led to *new* connections being made? *(e.g. enquiries from previously unfamiliar people in the neighbourhood, joining of local /national environmental groups, good interactions with neighbours)*
   - Has it contributed to a sense of community amongst the residents?

7. **Has the presence of the LZC energy technology in the home caused you to behave or think differently to before?** (4.05pm)
   - Has there been any change to the level of environmental concern you feel? *(e.g. are you more aware of climate change and non-renewable fossil fuel usage?)*
   - Has this led to observed changes in consumption levels & pattern?
   - Any tailored evidence of the rebound effect?

- Has having the LZC technology led you to feel uncomfortable with previous behaviour and, if so, what has been the consequence of this?
- **Has the technology affected activities/attitudes outside the home?**
- Has the LZC technology altered your self-identity?
- Has it instigated any sense of pride? If so, what has been the effect of this?
- [Has the use of the technology led to any unexpected effects?]

8. **What degree of communication in the home is there w.r.t. the technologies and between who?** (4.10pm)
    - Is it a normal topic of everyday conversation?

9. **What structural aspects of the dwelling, & interactions with other items, influence the way in which the LZC technology is used?** (4.15pm)
    - Examples
    - Can you suggest any changes in the structural aspects of the home etc. that might improve the ways in which the technology is used/maintained or that might increase your levels of engagement with it?

10. **Has any organisation proactively made contact with you in relation to your LZC technology (e.g. maintenance companies, Council, residents' association)?** (4.20pm)
    - Would any such contact have been welcomed?
    - What external sources of information are used & what is the mode of access?
    - Any resident's association?
    - Which sources of information do you trust most (and least)?
    - [Are you involved in any existing formal/informal network or association in the locality or beyond?]
        - w.r.t. LZC technologies?
        - w.r.t environmental issues more generally?]

11. **How is the LZC technology perceived?** (4.25pm)
    - By household members? *(e.g. symbol of modernity?)*
    - By friends, family & neighbours?
    - [What do you consider to be the main positive/negative characteristics/attributes of the technology?]
    - [Has the perception of the technology changed over time?]

- Are you concerned about the reliability and maintenance issues relating to the technology?
- How do users perceive themselves?

12. Technology specific details (4.30pm)

- What technology have other residents in the new development got?
- Go through technology specific questions

13. Would you like assistance/ information/ training/ support etc. in relation to the LZC technologies - via a new local group of community members (self-help group which will seek external assistance as required)? (4.35pm)

- Can you suggest any suitable local venues where participants can meet up?
- On what days and at what times could you potentially participate in such a new local group?

14. Any comments

- Are there any neighbours you could encourage to take part in the interviews?
- Do they have a contact number/name for any Management Company involved?
- Feedback on policy

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Appendix 9

Participant Consent Form

Research into Low and Zero Carbon (LZC) Energy Technologies in the Home

You have kindly contributed to the first phase of my research by returning the completed questionnaire, entitled 'Research into Low and Zero Carbon (LZC) Energy Technologies in the Home'. You have also expressed a willingness to participate in the second phase of the research study, i.e. this interview, where we will be exploring in more detail how the LZC energy technology installed in your home influences your behaviour and to what extent the performance of this technology is being maximised.

This form outlines how the interview will be conducted and how the information you provide will be handled. Royal Holloway, University of London, issues detailed guidance on how to conduct research in an ethical manner, and this form has been written to ensure this guidance is followed. Could you please, therefore, read the following information and sign to demonstrate your understanding of the information given and your wish to participate in the research:

- This interview will be audio recorded in order to ensure an accurate record is made of our discussion. This removes the need to rely on potentially faulty recollections and inadequate note taking, on my part. Removing the need to take notes will also enable me to listen more attentively to what you are saying and to tailor our discussion accordingly.

- The recording will be kept securely and will be typed out to form a transcript that will be analysed as part of the research. All references to names and other identifying details will be removed from the transcript. All information given will be treated in confidence and will only be used for my research purposes.

- If requested, I will send the transcript of our interview recording back to you. This will give you the opportunity to identify any additional text that should be changed so as to ensure your anonymity or to improve accuracy.

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- The research results will be written up and presented in different formats, tailored to various audiences such as householders, planners, developers, architects and the academic community (e.g. in the form of a PhD thesis and published research papers). Quotations from interviews may be used to illustrate research findings, though the names of those making these quotations will not be disclosed.

- If you have any concerns now that we should take account of, or if any concerns arise during the interview, please do not hesitate to let me know. Similarly, if you have any questions relating to the research, please ask. Should you at any point wish to stop the interview, we will do so.

More than 30 local householders within the borough of Woking have kindly agreed to be interviewed. Your collective contribution will constitute a key part of this research.

Confirmation and consent

I understand the aims of the research, how the interview will be conducted and how the information provided will be carefully handled to ensure my confidentiality and anonymity. I am willing to participate in this recorded interview, and I know that I can raise any concerns or questions I might have during the process. I assign the copyright of my contribution in this interview to Royal Holloway University of London, for the purposes of the stated research.

Participant's name:

1.____

2.____

Signature 1: ___________________________________

Signature 2: ___________________________________

Date: ______________

Researcher's name: ______________________________

Signature: _____________________________________

Date: ______________

Appendix 10 - What LZC technology symbolised for interviewees

Technology is a symbol of progress and/or efficiency
'I suppose it's a more efficient use of power …' (ID256, STHW)
'For me it is a symbol of progress. When I go to stay at my parents' house, they don't have it. I find it quite weird now. I'm very aware when I go there they switch their gas boiler on to heat the water: 'Oh, do you want a bath, I'll put the hot water on'. It's quite a different sort of world. I don't do that.' (ID155, STHW)
'Direction of travel' (ID608, CHP)
Technology is a symbol of the low carbon economy /low carbon future/greener future
'Low carbon economy or low carbon future.' (ID 424, MVHR & STHW)
'A greener future.' (ID805, CHP, communal biomass & MVHR)
'I'd say it was a symbol of more and more people, cases like Councils and things like that, accepting that we do need to move on to low carbon. I see it as a first step towards that, not the final solution. A kind of sign that it's becoming the majority opinion, particularly in Woking where they are pretty good about things like that, that we need to do something about this, and just the best way to do it is to just kind of give it to people, and they live with it.' (ID833, STHW)
Do not think of the technology as a symbol of anything, but regard it as something useful or a household appliance
'It was useful, is probably the best way. It's nice to know you had it, but I couldn't really think of it as a symbol. It was just there, again probably because a lack of understanding. Just sort of there and you knew it was doing something but how much of a something it was doing, you just didn't really know.' 'Just another household appliance in effect.' (ID295, STHW)
Do not think of the technology as a symbol of anything, but regard it as just an ugly building element
'Just another building element that looks a bit ugly on the top. You know, there are 19 panels on there, strutted on the various roofs. I guess, in a way, the building would have been better if the solar panels weren't there.' (ID829, STHW)
Technology is a form of social engineering
'I'm against this micromanagement of people by Councils – I don't think they have any right to do it at all. I don't think social engineering is …' '… we don't want it rammed down our throats. We're not prepared to have it.' (ID804, CHP, communal biomass & MVHR)

Table A10.1 What LZC technologies symbolised for the interviewees

Appendix 11 – Suggested interview venues and times

A. Suggested interview venues and times - Research into Low & Zero Carbon (LZC) Energy Technologies

Please have a look at the following two tables and indicate which venues and times would be convenient to you for our meeting (ideally indicate two or three slots). If certain venues are convenient for you, but the time slots given are not, please provide alternative dates and times you could make. Please note that the community centres close at 4pm or 5pm and are not open at the weekend. If it is not convenient for you to get to any of these venues, please let me know and we will find a suitable alternative.

Community Centres	Tuesday 31st January	Wednesday 1st February	Friday 3rd February	Saturday 4th February	Sunday 5th February	Monday 6th February	Tuesday 7th February	Wednesday 8th February	Thursday 9th February	Friday 10th February
St. Mary's, Byfleet[1]		12.30pm 2.30pm				10.30am 12.30pm 2.30pm				
Moorcroft , Westfield[2]	10.30am 12.30pm 2.30pm							10.30am 12.30pm 2.30pm		
Parkview, Sheerwater[3]			10.30am 12.30pm 2.30pm							
The Vyne , Broadway[4]							1.00 pm 2.30pm			
Woking Leisure Centre[5]				9.30am 11.30am 1.30pm 3.30pm 5.30pm					10.30am 12.30pm 2.30pm	10.30am 12.30pm 2.30pm

Community Centres	Saturday 11th February	Sunday 19th February	Monday 20th February	Tuesday 21st February	Wednesday 22nd February	Thursday 23rd February	Friday 24th February	Saturday 25th February	Sunday 26th February
St. Mary's, Byfleet[1]					12.30pm 2.30pm				
Moorcroft , Westfield[2]									
Parkview, Sheerwater[3]			10.30am 12.30pm 2.30pm						
The Vyne , Broadway[4]						10.30am 12.30pm 2.30pm			
Woking Leisure Centre[5]	9.30am 11.30am 1.30pm 3.30pm 5.30pm	9.30am 11.30am 1.30pm 3.30pm 5.30pm		10.30am 12.30pm 2.30pm			10.30am 12.30pm 2.30pm	9.30am 11.30am 1.30pm 3.30pm 5.30pm	9.30am 11.30am 1.30pm 3.30pm 5.30pm

B. Address details for suggested venues

1. St. Mary's, Stream Close, Byfleet, Surrey, KT14 7LZ (http://www.woking.gov.uk/community/older/centresforthecommunity/stmarys2)
2. Moorcroft, Old School Place, Westfield, Woking, GU22 9LY (http://www.woking.gov.uk/community/older/centresforthecommunity/moorcroft)
3. Parkview Centre for the Community, off Blackmore Crescent, Sheerwater, Woking, GU21 5NZ (http://www.woking.gov.uk/community/older/centresforthecommunity/parkview)

4. The Vyne, Broadway, Knaphill, Woking GU21 2SP (http://www.woking.gov.uk/community/older/centresforthecommunity/thevyne)
5. Woking Leisure Centre, Woking Park, Kingfield Road, Woking, Surrey, GU22 9BA (http://www.freedom-leisure.co.uk/centres.asp?section=840&sectionTitle=woking+leisure+centre)

C. Interview times and venues convenient for you (selected from the previous two tables)

Venue				
Date				
Time				

D. Alternative interview times and venues suggested by you (if nothing proposed in the tables is convenient)

Venue				
Date				
Time				

Please e-mail the completed form back to lise.andreassen.2010@live.rhul.ac.uk. Alternatively, you can send the form back a.s.a.p. to: Lise Andreassen, Department of Geography, Royal Holloway, University of London, Egham, Surrey, TW20 0EX.

Thank you for your participation in this research. **25/1/12**

Appendix 12 – Summary of survey results posted to householders

Research into low and zero carbon energy technologies in new homes (March 2012)

Research is currently being undertaken in the borough of Woking to find out how occupants of new homes are interacting with any low to zero carbon (LZC) energy technologies that have been installed. The types of such technologies that are being installed (as reported by those that have participated in the research) are listed in Figure 1 below. The aim of the research is to explore how the installed LZC energy technologies are influencing the behaviour of householders and to what extent the performance of these technologies is being maximised.

The graphs in this document summarise a selection of the results obtained from the 1st phase of this research, which was undertaken between October 2011 and January 2012 and achieved via a postal questionnaire. 120 occupants of new homes participated in this survey of householders' experiences with LZC energy technologies. The 2nd phase of the research is now in progress and involves interviewing householders to obtain a selection of more detailed accounts of their experiences.

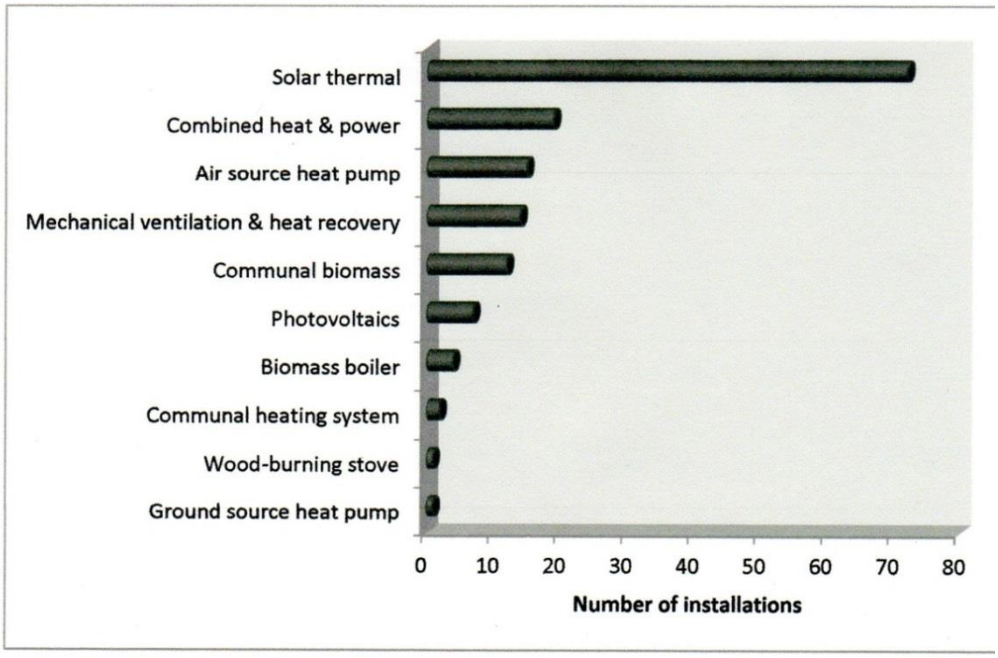
As part of the 3rd phase of the research, a local network of LZC energy technology users is being set up in the borough of Woking. Members of this network will be able to exchange information and experiences in relation to their installed technologies, and will be able collectively to decide what aims the network should have (e.g. as a social network, the provision of training, assistance with trouble-shooting, providing feedback to developers and planners).

If you would be happy to talk about your experiences with any installed LZC energy technology, or would like to join the local network of LZC energy technology users, please send an e-mail to lise.andreassen.2010@live.rhul.ac.uk.

The full research results from Phase 1 will be on display shortly. The launch event for the local network of LZC technology users will also be taking place in the next few weeks.

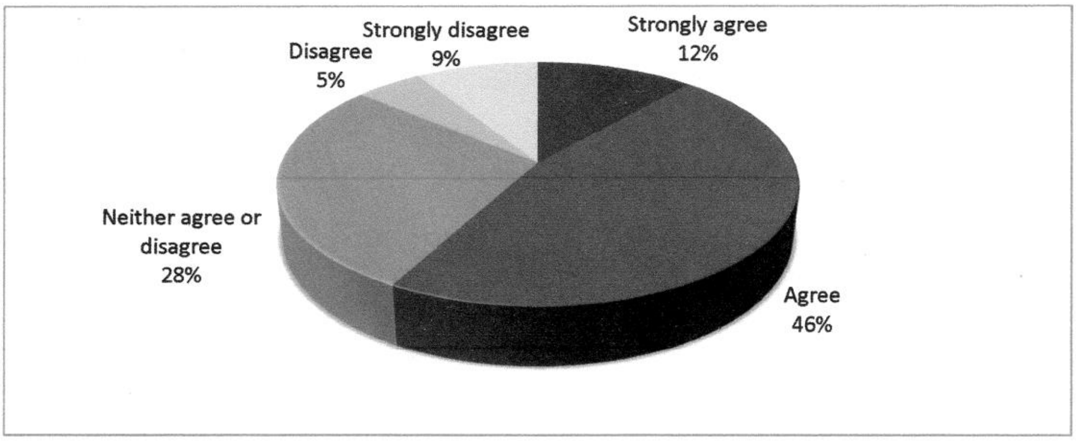
Please do not distribute these results elsewhere as the research project is still in progress.

1. Which low and zero carbon (LZC) energy technologies are installed?

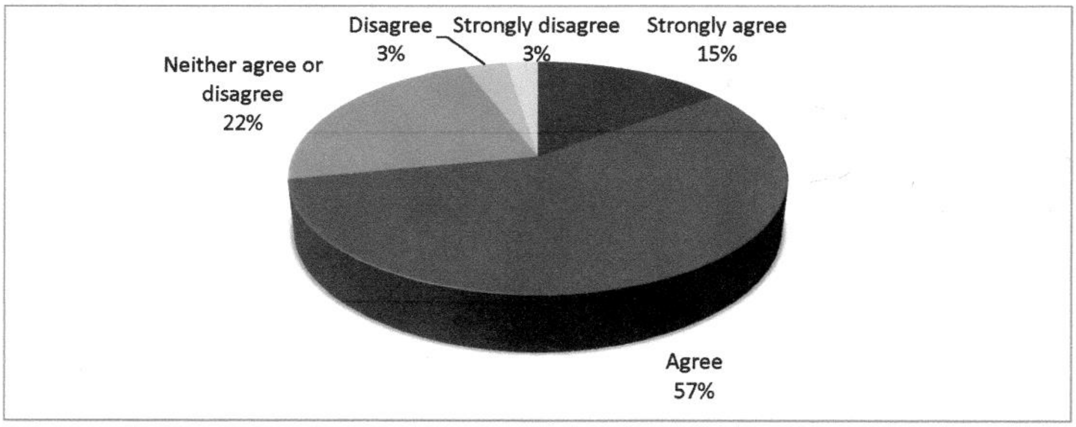


Lise Andreassen, Department of Geography, Royal Holloway University of London, Egham, Surrey, TW20 OEX, March 2012, lise.andreassen.2010@live.rhul.ac.uk

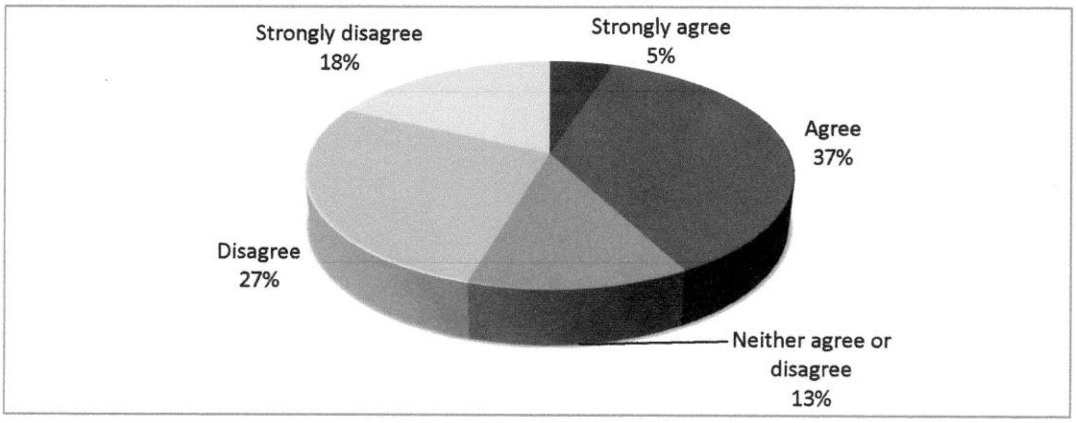
2. 'You are satisfied with the performance of your LZC energy technology'



3. 'You are interested in the ways your LZC energy technology works and what effects its performance levels'

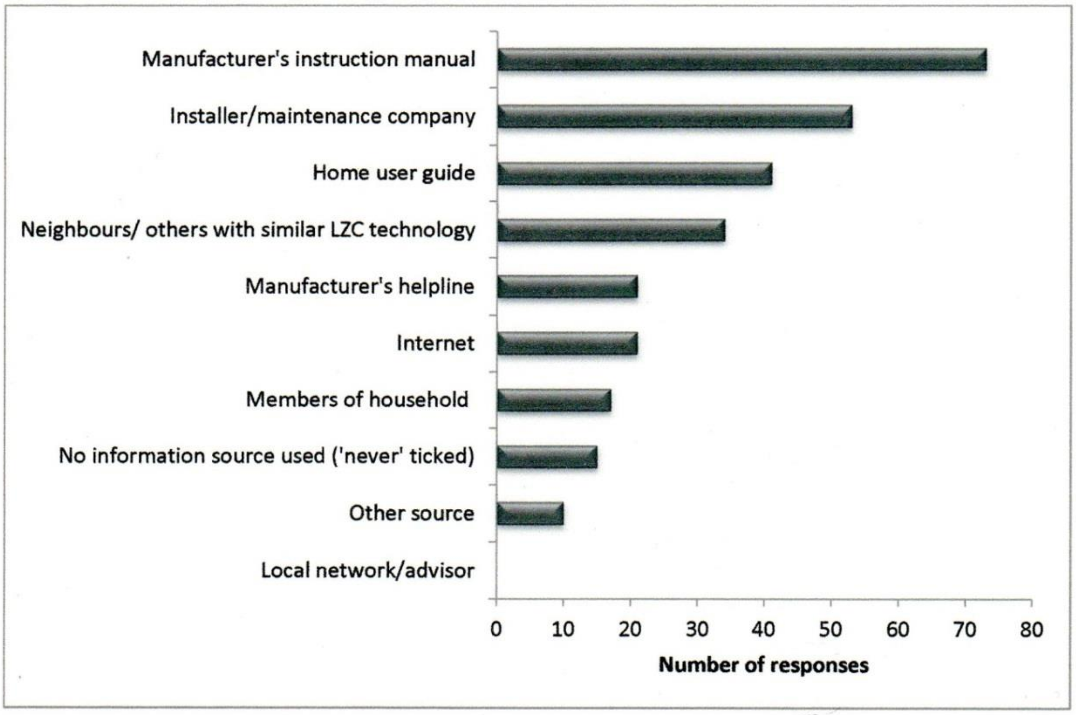


4. 'The developer or landlord has provided you with sufficient information on operating and maintaining your LZC energy technology'

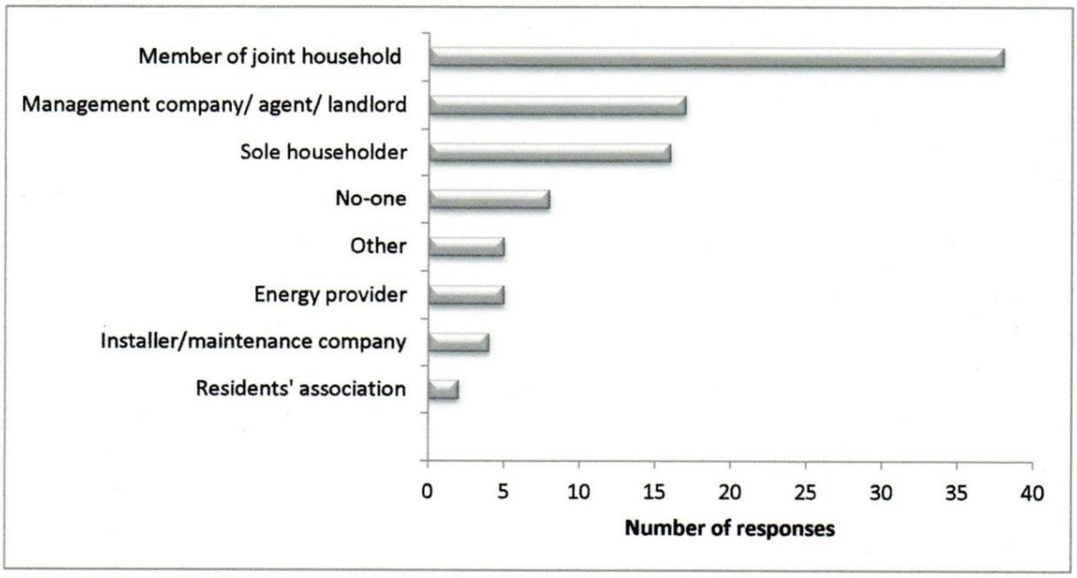


Lise Andreassen, Department of Geography, Royal Holloway University of London, Egham, Surrey, TW20 OEX, March 2012, lise.andreassen.2010@live.rhul.ac.uk

5. Which sources of information do you use to help you maximise the performance of and benefits from your LZC energy technology?



6. Who ensures that the LZC energy technology is operating efficiently and is maintained as necessary?



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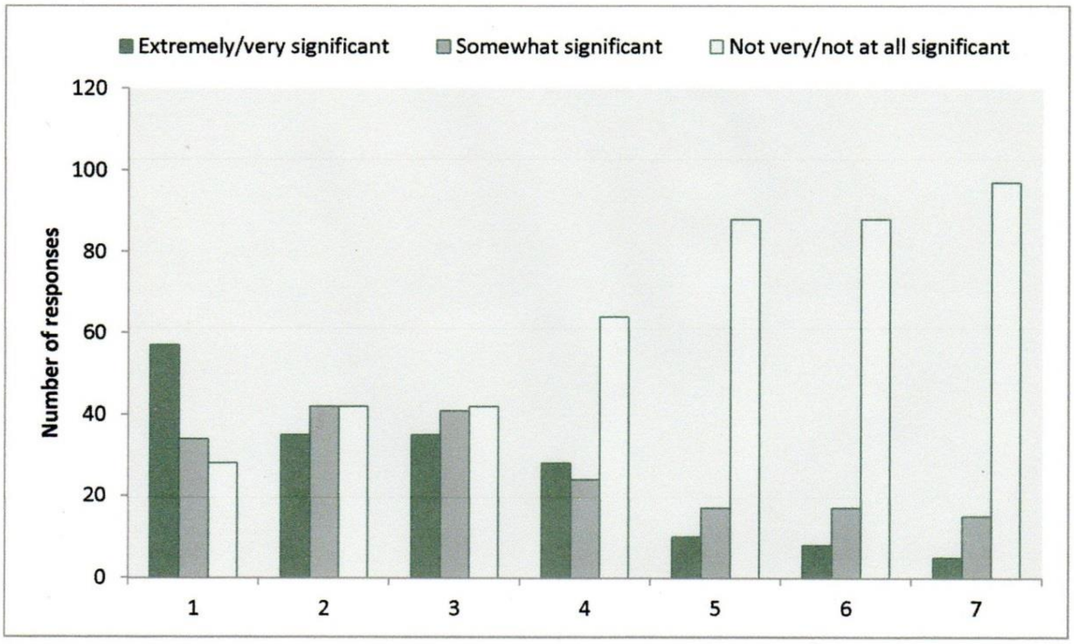
7. How significant have the following *incentives* been for improving the performance of your LZC energy technology?



Incentives ranked in <u>decreasing</u> order of significance

1. Reducing energy costs
2. Reducing carbon dioxide emissions (and helping to combat climate change)
3. Reducing demands on non-renewable fossil fuels (i.e. oil, natural gas, coal)
4. Producing more of your own energy (i.e. promoting self-sufficiency)
5. Pleasing particular household members
6. Interacting with and gaining feedback from display monitors and meters
7. Demonstrating success to others **outside** of your household

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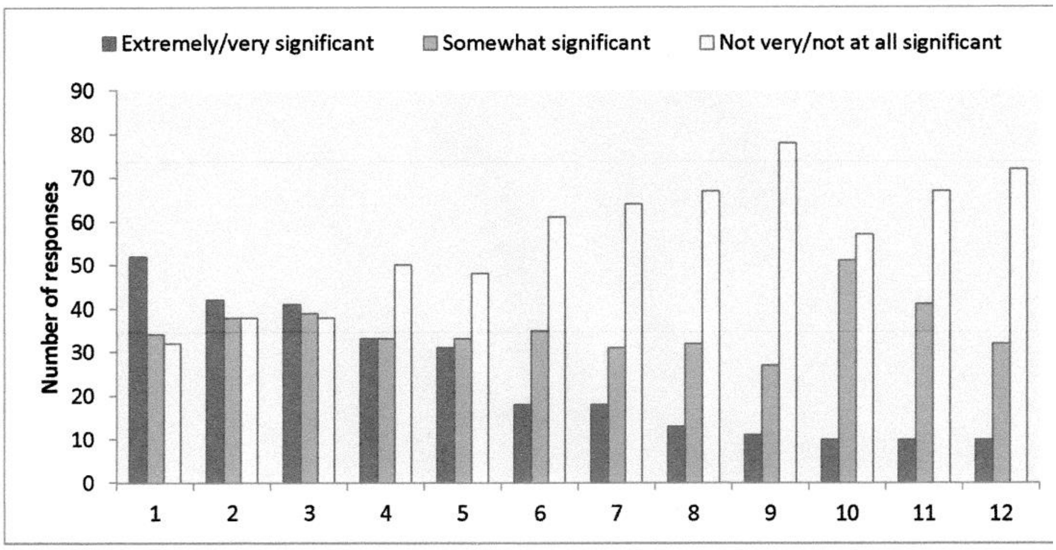
8. How significant are the following potential *obstacles* to improving the performance of your technology?



Obstacles ranked in <u>decreasing</u> order of significance

1. An insufficient understanding of the best operating and maintenance procedures to follow for the LZC energy technology
2. Insufficient time/ability to assess and monitor the technology's performance levels
3. The time and effort needed to find out how best to operate and maintain the LZC energy technology
4. The inaccessibility of component parts of the LZC technology for maintenance etc.
5. The 'invisibility' of the LZC energy technology within the home
6. Insufficient opportunity to discuss your LZC energy technology with other owners
7. You consider that your contribution to addressing these environmental concerns would be too insignificant to bother about
8. An insufficient interest in climate change or in the depletion of non-renewable fossil fuels (i.e. oil, natural gas, coal)
9. A lack of interest in the cost of energy
10. Your personal routines/habits within the home that you **do** want to change
11. Your personal routines/habits within the home that you **do not** want to change
12. The routines, habits and attitudes of other members of your household

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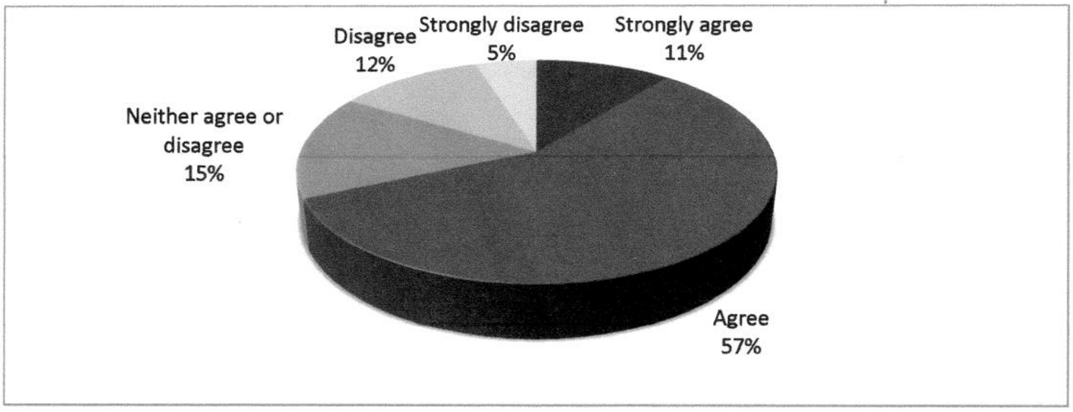
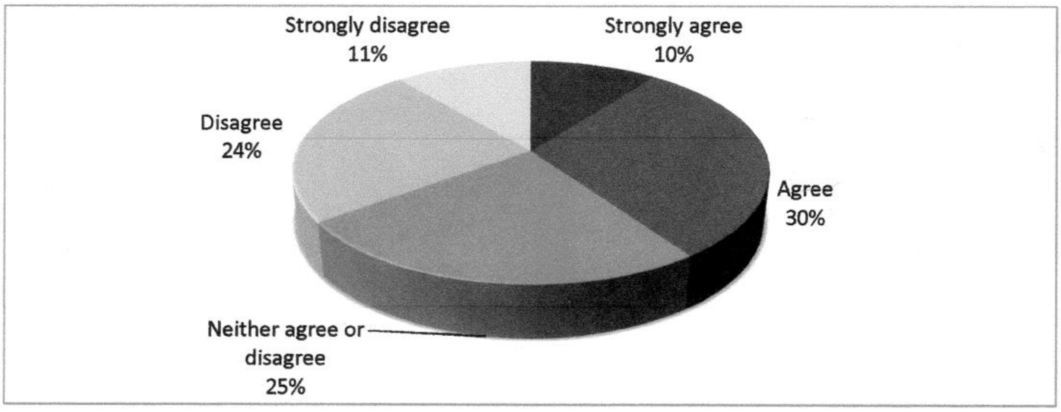
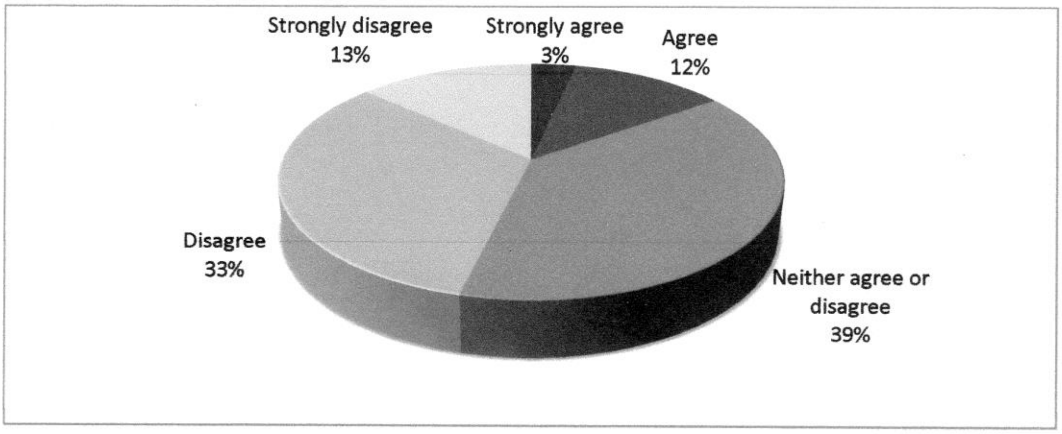
9. 'You understand how your household practices may impact on the benefits gained from your LZC energy technology'



10. 'The presence of your LZC technology has caused you to do things differently *inside* your home'



11. 'The presence of your LZC technology has led you to behaving differently *away from* your home due to an increased environmental awareness'



Lise Andreassen, Department of Geography, Royal Holloway University of London, Egham, Surrey, TW20 OEX, March 2012, lise.andreassen.2010@live.rhul.ac.uk

Appendix 13 – Householders' exhibition & network launch invitations

INVITATION

Sunday 29th April 2012 - anytime between 1pm and 3pm

Come and find out more about other local residents' experiences with low & zero carbon energy technologies at a private exhibition

Venue: The Ambassador Room at The Lightbox, an iconic, award-winning museum & gallery in Woking town centre

The Lightbox, Chobham Road, Woking, GU21 4AA, www.thelightbox.org.uk/home

For further information on the private exhibition, contact:
lise.andreassen.2010@live.rhul.ac.uk

Children welcome

INVITATION

Sunday 29th April 2012 – 3.15pm to 4.30pm

1st meeting of the local network of low & zero carbon energy technology users

Come and help shape the aims of this new network

Venue: The Ambassador Room at The Lightbox, an iconic, award-winning museum & gallery in Woking town centre

The Lightbox, Chobham Road, Woking, GU21 4AA, www.thelightbox.org.uk/home

RSVP: lise.andreassen.2010@live.rhul.ac.uk

Appendix 14 - First exhibition - posters displayed

Department of Geography

Optimising low and zero carbon energy technologies in new homes

Lise Andreassen

Royal Holloway University of London

Royal Geographical Society with IBG

Background to this exhibition

Given the Government's policy of achieving 'zero-carbon' new homes by 2016, the extent to which low carbon and renewable energy technologies are designed into new homes is set to increase significantly. So it is especially important to learn *now* from the experiences of existing users of these technologies, such as yourself. Overall, this research will investigate:

- how such technologies are used in practice and what experiences occupants have regarding these new forms of technology;
- whether these low carbon and renewable energy technologies are likely to deliver the carbon dioxide reductions envisaged; and
- how the design/installation/use of these energy technologies can be improved.

Relevant research results will be communicated to local planners, developers, housing associations, architects and technology manufacturers and installers.

The borough of Woking was selected for the research as it has a large number of new homes built with installed low and zero carbon (LZC) energy technologies. All occupants of these new homes (as identified) have been invited to participate in this borough-wide research project.

This exhibition is based mainly on the results from the first phase of this research.

The main objectives for the overall research project are as follows:

Objective 1
To conduct a post-occupancy evaluation of the drivers and barriers that affect householder behaviour in relation to optimising installed LZC energy technologies in new homes.

Objective 2
To assess the wider effects of LZC energy technologies on users and others (e.g. what 'spill-over' effects on seemingly unconnected activities and behaviours have the technologies led to?).

Objective 3
To initiate the participatory creation of a borough-wide, householder support network to promote improvements in the installation and usage of LZC energy technologies.

The main objectives of this exhibition are:

- **To provide feedback to local residents on the research results obtained so far;**
- **To enable local residents to compare their experiences with others;**
- **As a thank you to those that have already participated in the research; and**
- **As an invitation to participate for those that have not yet been involved.**

The research project is comprised of three phases:

Phase 1 (completed)
The initial phase of the research, undertaken between October 2011 and January 2012, consisted of a questionnaire that was distributed to all new homes (as identified) that had been granted planning permission in the borough of Woking since 2005. 120 occupants participated in this survey of householders' experiences with installed LZC energy technologies.

Phase 2 (in progress)
The second phase of the research, which commenced in February 2012, entails 1-hour interviews (at a place & time convenient to you). The aim is to obtain a selection of more detailed accounts of experiences with LZC energy technologies. If you would be happy to be interviewed, please let me know.

Phase 3 (starting)
The third phase of the research involves the setting up and running of a householder support network, which aims to promote improvements in the installation and usage of LZC energy technologies.

Members of this network will be able collectively to decide what aims the network should have (e.g. as a social network, the provision of training, assistance with trouble-shooting).

The planned launch of this network is today at 3.15pm in this room. I hope you are able to come along and help shape its aims.

This project was supported by the Royal Geographical Society (with the Institute of British Geographers) with a Postgraduate Research Award

Royal Geographical Society with IBG
Advancing geography and geographical learning

Royal Holloway University of London

Which low and zero carbon (LZC) energy technologies are installed?

The number of new homes with installed LZC energy technologies
Over 1000 occupants of new homes, within the borough of Woking, were asked to complete a questionnaire relating to any LZC energy technologies that had been installed by the developer in their home. The questionnaires were distributed between October 2011 and January 2012. From the feedback received, it is estimated that approximately 670 of these new homes have actually been equipped with or are served internally (e.g. via a communal heating system) by some form of this technology. It is the households in these homes that form the focus for this research.

The remainder of the new homes surveyed are not served, within the home, by any form of LZC energy technology for a variety of reasons, such as:

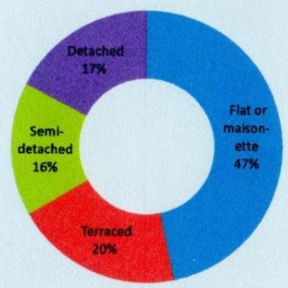
- The LZC energy technology installed serves communal facilities only;
- The LZC energy technology is concentrated in other homes within the development;
- The developer commenced but did not complete the installation of the LZC energy technology.

Types of LZC energy technologies installed
The LZC energy technologies which these householders identified as being installed are summarised below in Figure 3. Solar thermal systems, which provide hot water, are the predominant type of LZC energy technology, and have been installed by developers in 60% of the participating householders' homes. The next most frequent technologies installed are combined heat & power systems, air source heat pumps, mechanical ventilation & heat recovery systems and communal biomass systems, each present in 10% - 16% of households.

25 of the 120 participating households have more than one type of LZC energy technology installed.

From conversations held, it appears that householders are not always aware when there is a mechanical ventilation and heat recovery system installed in their home. In other instances, there may be some confusion as to what type of system they actually have installed (e.g. does the solar panel provide hot water or electricity?). For these reasons, the data shown in Figure 3 may not be entirely accurate.

Figure 1. Dwelling type



Response rate
120 of the targeted households completed and returned the survey questionnaire, which represented nearly an 18% return rate.

Dwelling type
The mix of dwelling types occupied by the participating householders are summarised in Figure 1.
47% of participants have moved into new flats. Most householders have been living in their new homes for 2 or less years (refer to Figure 2).

Figure 2. Length of time in home

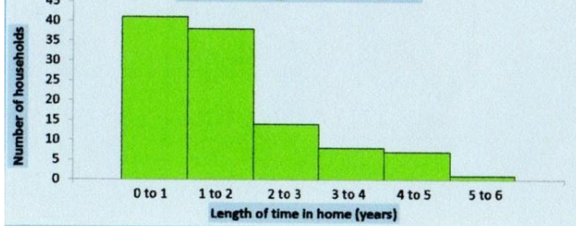
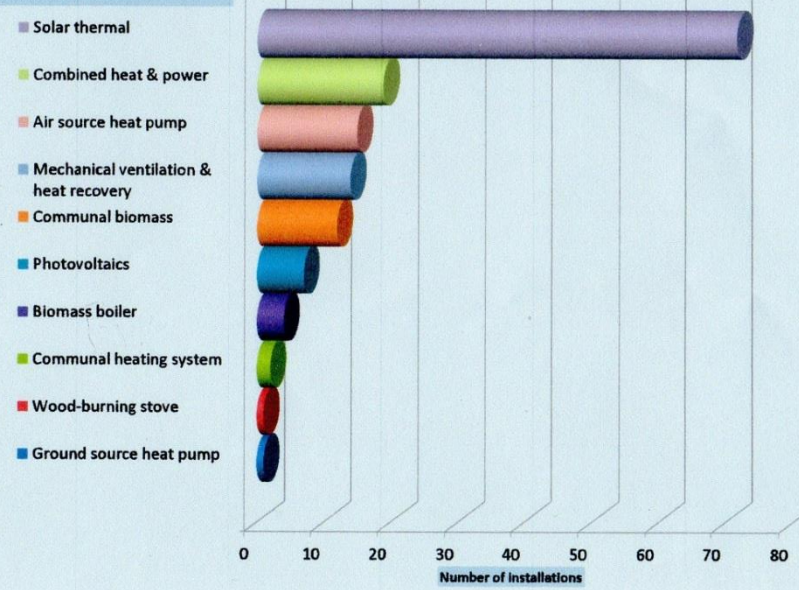


Figure 3. Type of LZC energy technology installed



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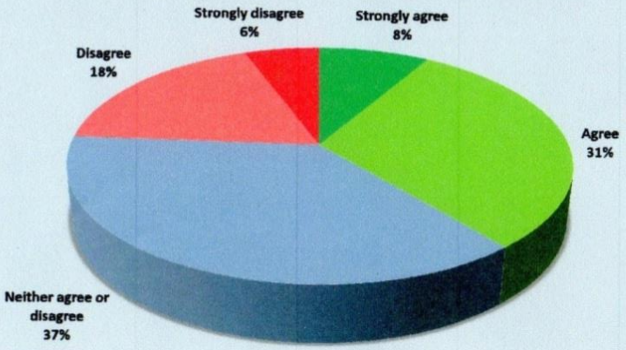
Royal Holloway University of London

Is the presence of low and zero carbon (LZC) energy technologies a positive influence on householders when selecting a new home?

Figure 1. Responses to the statement: 'The presence of the LZC energy technology was a positive influence on your choice to live in your home'



Overall response

39% of householders agree or strongly agree that the presence of the LZC energy technology in their home had a positive influence on them selecting that property to live in (Figure 1). 24% disagree or strongly disagree that this was the case and the remaining 37% of householders hold a neutral position on this statement.

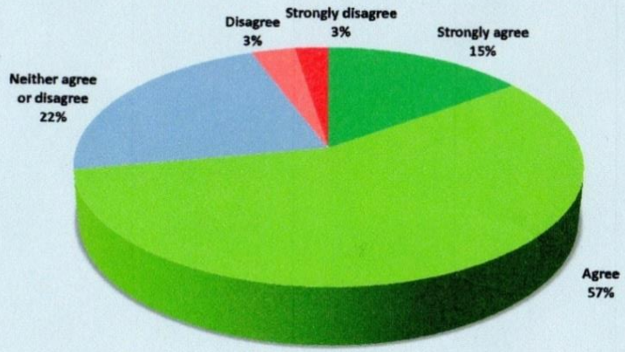
From comments made on the returned questionnaires and from conversations held with occupants of these new homes, it is apparent that the LZC energy technology is, in certain cases, not a feature that is drawn attention to by those marketing the properties for sale or rent.

Individual responses

- "Until I received this questionnaire, I was not aware of the LZC in my house. I do care about the environment, but have not read through the literature provided by my landlord – I rent the property."
- "... we did not buy the apartment for its propensity to save the world from greenhouse gases but rather to save ourselves from huge fuel bills. Our motives were and remain wholly selfish."
- "Although I am interested in LZC to save money and polar bears, the flat comes with district heating – [it] wasn't a factor in my decision."
- "The CHP [combined heat & power system] did not affect my choice of purchase."

Are people interested in how their LZC energy technology works and what effects its performance level?

Figure 2. Responses to the statement: 'You are interested in the ways your LZC energy technology works and what effects its performance levels'



Overall response

Although only 39% of householders considered that the LZC energy technology was a positive influence on them selecting their property, Figure 2 shows that 72% are interested in the ways in which their technology works and what effects its performance levels. Only 6% disagree or strongly disagree with this statement and the remaining 22% of householders hold a neutral position.

As referred to on another poster (Number 7), reducing energy costs is the most significant incentive for householders to improve the performance of their LZC energy technology i.e. people are particularly interested in the performance of their technology and how it works because they wish to maximise their cost savings.

Difficulty in comparing energy costs

A number of householders have made the comment that it is difficult to know whether they are spending less on energy now than if they had only conventional heating systems installed. This uncertainty arises as householders have often moved into a different size and age of property, and thus they do not have a similar situation to compare their current energy costs with.

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How satisfied are householders with the performance of their low and zero carbon (LZC) energy technologies?

Comments by solar thermal users

- "The system works so well and very effective so less energy."
- "Solar water heating reduced my gas bill to less than £40 for the summer (incl. standing charge)."
- "It works well but at the cost of £4000 it does not pay back – either ground source or air source heat pumps would be more efficient. One of the panels leaked – and could be prone to high maintenance costs."
- "I am probably not the best person to ask about this as I have little interest in saving a few ££s (fortunately)."
- "The solar panel we have does little to reduce impact on the environment as it only works when the day is sunny!!"
- "Solar panels are totally useless in this country – the manufacturer said we need at least 3-4 days of at least 28° C in order to get enough hot water."
- "It's useless – seems to generate very little slightly warmed water" "It is rubbish – advert says "free piping hot water" – barely warms to 30°C."
- "I have experienced 2 major leaks from the system causing ceilings to collapse and other owners have had problems. The system is currently isolated and I would happily strip it out to give more useful storage space."

Comments by air source heat pump (ASHP) users

- "The house is electricity only. The cost of running it using air source heat pump is greatly reduced.'
- "Air source heat pump consumes vast amounts of electricity and I have since discovered this should be fitted only in conjunction with solar PV [photovoltaic] panels, to offset electricity consumption."
- Last winter, one householder had trouble with their ASHP unit. The 1st and 2nd floors were warm enough but not the downstairs, so they had to buy extra heaters. They had not been told properly how the ASHP works. They have under-floor heating throughout and miss having radiators.
- One householder stated she was not happy with her ASHP.
- Another householder called his ASHP 'horrendous'.

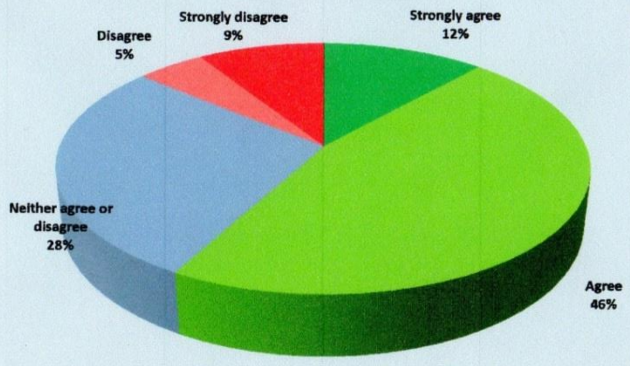
Overall response

58% of householders agree or strongly agree that they are satisfied with the performance of their LZC energy technologies (Figure 1). Only 14% disagree or strongly disagree with the statement that they are satisfied and the remaining 28% of householders hold a neutral position on this.

Individual responses

The comments made by householders have been segregated by technology type into the 5 other text boxes on this poster. Some comments were obtained from doorstep conversations from people who did not subsequently return completed questionnaires.

Figure 1. Responses to the statement: 'You are satisfied with the performance of your LZC energy technology'



Comments by combined heat & power (CHP) users

- "There's an automatic temperature control system built in flat. So far I've never changed the settings or had any problems. So the entire system is almost transparent to me – and it is quite comfortable."
- "Downside to CHP is that I don't like being locked into one supplier of energy. It is anti-competitive."

Comments by mechanical ventilation & heat recovery (MVHR) users

- "Noisy to run, no temperature difference when ran."
- One householder who has a MVHR system has not noticed any benefits from running it.

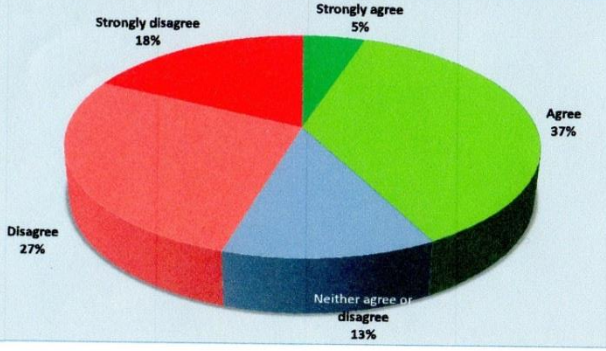
Comments by combined CHP/biomass/gas system users

- "The biomass boiler is totally useless – so expensive it is unusable – has to be switched on twice yearly to satisfy rules. Makes a total nonsense of any attempt to save energy and extremely demotivating."
- "[The developer & energy contractors] offered us a "unique monitoring system" which was so innovative it would read the heat meters from outside our property. The only innovation here is that it isn't going to happen. We were told that the HIU [hydraulic interface unit] controls are pre-set and we were instructed: DO NOT ADJUST ANY OF THESE CONTROLS. We were personally instructed not to open the cabinet. Six months later, all of this has changed. There will be no remote monitoring and we must open the cabinet and read our own, quite meaningless figures. Because the water heating settings were maximised at 'tepid', we were shown how to turn the whole thing up manually for 'normal living'."
- One householder does not believe they should be paying more for their energy provision in order to reduce carbon dioxide emissions.
- "It was installed purely for planning permission [i.e. CHP & biomass boiler] and provides residents with very little benefits, and actually costs us more than a conventional heating system due to the high maintenance costs."
- "... the biomass boiler and CHP still have not been activated/commissioned. We, the residents, are very frustrated. The commissioning appears to be in the hands of the management company ..."
- "In our apartments we have had issues with our energy system as the developer installed it to meet planning regulations but grossly underestimated the running costs."

Do householders consider that the developer or landlord has provided them with sufficient information on operating and maintaining their LZC energy technology?

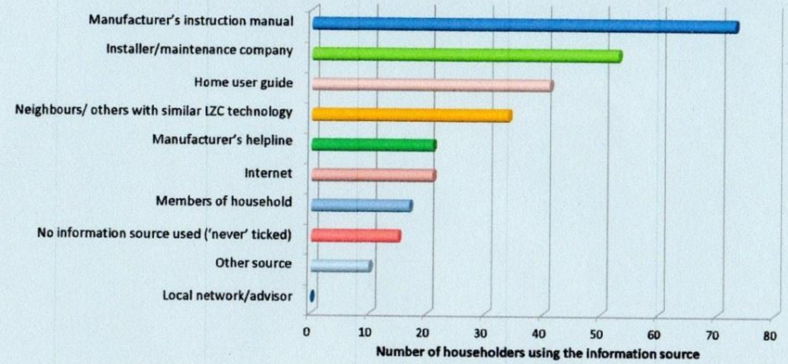
Overall response
42% of householders agree or strongly agree that their developer (or landlord) has provided them with sufficient information on how to operate and maintain their LZC energy technology (Figure 1). However, a slightly higher proportion of householders , at 45%, disagree or strongly disagree that sufficient information was provided.

Figure 1. Responses to the statement: 'The developer or landlord has provided you with sufficient information on operating and maintaining your LZC energy technology'



Individual responses
- "Solar panels were provided with the house – we have been given no documentation for the system!!"
- "Information supplied with house was very vague & aimed at installers not users – we also had to request it!"
- "No information at all."
- "When moving into this new flat, we had very little information given to us. The manager is of little use."
- "Developers are rewarded for installing such devices, but they should also be required to provide sufficient training/ documentation on their use."
- One householder stated that there is something in the loft, but she is not sure what it is. She does not think it is switched on. She moved in after tenants had been living there. The place had been cleared and there was no information given to them on the house. [Neighbouring properties have mechanical ventilation & heat recovery (MVHR) systems.]
- Another householder stated that there may have been a sheet of information on the MVHR system at the time of moving in but she does not remember reading anything. There was no training given on how to operate the system. When sales people came round to show them how to open and close the windows, they did not mention the MVHR system. The extraction points are in the first floor ceiling by the stairwell and in the bathroom and shower room.

Figure 2. Which sources of information do householders use to help them maximise the performance of and benefits from their LZC energy technology?



Where do householders obtain their information from?
Given that 45% of householders disagree or strongly disagree that sufficient information was provided by their developer or landlord, which other sources of information do they turn to for assistance?

Figure 2 indicates that in addition to using the manufacturer's instruction manual and home user guide, information is commonly obtained from the installer of the technology and also neighbours with similar LZC energy technologies installed.

15 householders (representing 12% of those surveyed) stated that they have never sought out information that might help them maximise the performance of their LZC energy technology. In 3 of these cases, the LZC energy technology consisted of a communal system overseen by a management company.

To what degree are the LZC energy technologies maintained?
The degree to which installed technologies are maintained, is currently being explored in Phase 2 of the research. Of the 23 people interviewed to date, not one has been proactively approached by service providers (e.g. installers, manufacturers) in order to arrange for the servicing of their LZC energy technologies.

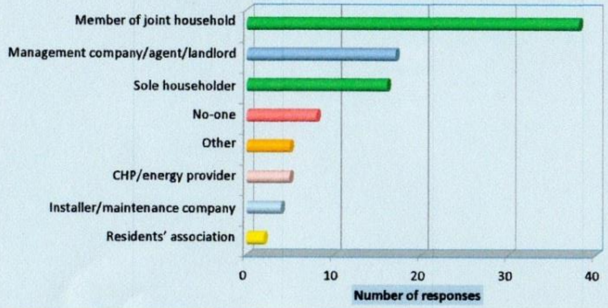
Service contracts (e.g. annual servicing) are not typically in place, except for communal heating and power systems. One or two householders have tried to arrange for service contracts, but have found an unwillingness on the side of the installers/manufacturers to enter into such arrangements.

One householder maintains the installed solar thermal system himself. Others only tend to have their systems checked when they believe there is a fault with it (as indicated by an abnormal noise, a leak, a suspected drop in performance etc.).

In summary, the degree to which the technologies are maintained is typically very limited and irregular.

Who ensures that the LZC energy technology is operating efficiently and is maintained as necessary?

Figure 1. Who ensures that the LZC energy technology is operating efficiently and is maintained as necessary?



Overall response
In 57% of new homes, someone within the household is identified as having the responsibility for ensuring the LZC energy technology is operating efficiently and is maintained as required. In other cases, an external organisation is allocated this role, such as the management company or landlord. In 8% of households, there is no-one taking on this responsibility.

Individual responses
"Cost of annual maintenance reduces the benefits to ourselves."
"No idea how to maintain."
"I am only occupant and don't bother."

Figure 2. Within joint households (where relevant), who ensures that the LZC energy technology is operating efficiently and is maintained as necessary?

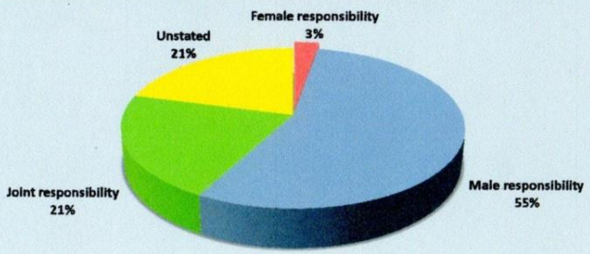
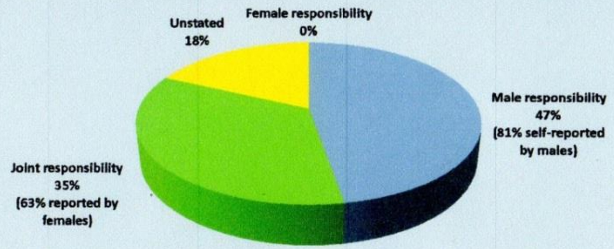


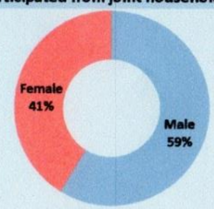
Figure 3. Within joint households, who has the main responsibility for making sure that day-to-day practices in the home make the most of the energy produced?



Where does the responsibility lie within households?
Figure 2 illustrates that within joint households, the responsibility for ensuring that the LZC energy technology is working efficiently is stated as resting predominantly with a male member of the household (55% of cases) or is shared jointly amongst the adults (21% of cases).

Similarly, when it comes to ensuring that a household's day-to-day practices make the most of the energy produced by the LZC energy technology, it is stated as being mainly the responsibility of a male member of the household (47%) or as being jointly shared amongst the adults (35%) (refer to Figure 3).

Figure 4. What gender are those that participated from joint households?



Age and gender of participants
As shown in Figure 4, men were responsible for completing 59% of the questionnaires from joint households.

The age distribution of all those that participated in the survey (i.e. from single and joint households) is illustrated in Figure 5.

Figure 5. What age are those that participated in the survey?

Figure 5. Age of participants

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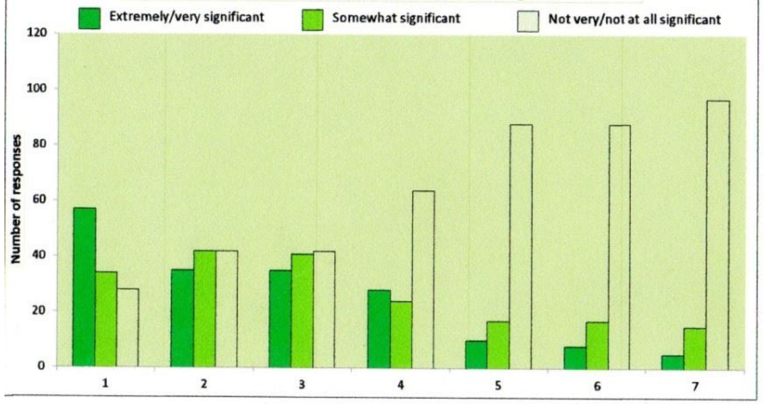
What do householders regard as the main *incentives* for improving the performance of their LZC energy technology?

Figure 1. How significant have certain *incentives* been for improving the performance of installed LZC energy technologies?



Incentives ranked in <u>decreasing</u> order of significance

1. Reducing energy costs
2. Reducing carbon dioxide emissions
3. Reducing demands on non-renewable fossil fuels (i.e. oil, natural gas, coal)
4. Producing more of your own energy
5. Pleasing particular household members
6. Interacting with and gaining feedback from display monitors and meters
7. Demonstrating success to others outside of your household

Additional incentives mentioned by householders

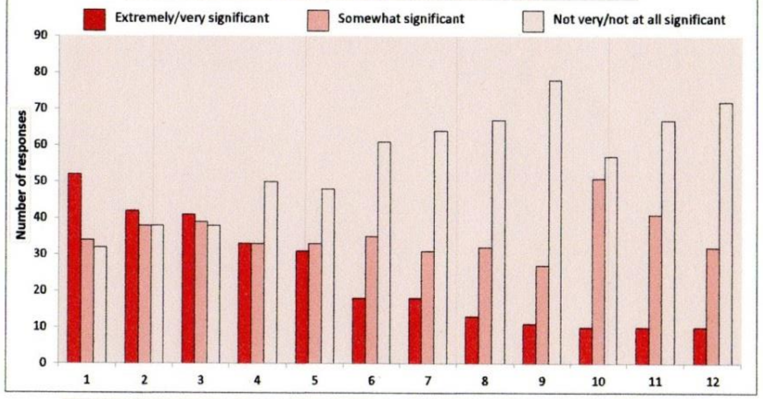
- "Making the house more comfortable"
- "Optimising efficiency"

Additional obstacles mentioned by householders

- "Unreliability"
- "The cost of LZC and the lack of efficiency."
- "Householder is 96 and has needed much support from a variety of people."
- "Developer who installed it did it to get planning permission & is not interested in it."
- "No way of knowing if it is effective, as energy bills are still high."

What do householders regard as the main *obstacles* to improving the performance of their LZC energy technology?

Figure 2. How significant have certain *obstacles* been to improving the performance of installed LZC energy technology?



Obstacles ranked in <u>decreasing</u> order of significance

1. An insufficient understanding of the best operating and maintenance procedures to follow for the LZC energy technology
2. Insufficient time/ability to assess and monitor the technology's performance levels
3. The time and effort needed to find out how best to operate and maintain the LZC energy technology
4. The inaccessibility of component parts of the LZC energy technology for maintenance etc.
5. The 'invisibility' of the LZC energy technology within the home
6. Insufficient opportunity to discuss your LZC energy technology with other owners
7. You consider that your contribution to addressing these environmental concerns would be too insignificant to bother about
8. An insufficient interest in climate change or the depletion of non-renewable fossil fuels
9. A lack of interest in the cost of energy
10. Your personal routines/habits within the home that you **do** want to change
11. Your personal routines/habits within the home that you **do not** want to change
12. The routines, habits and attitudes of other members of your household

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Characterising the obstacles to improved performance of LZC energy technologies

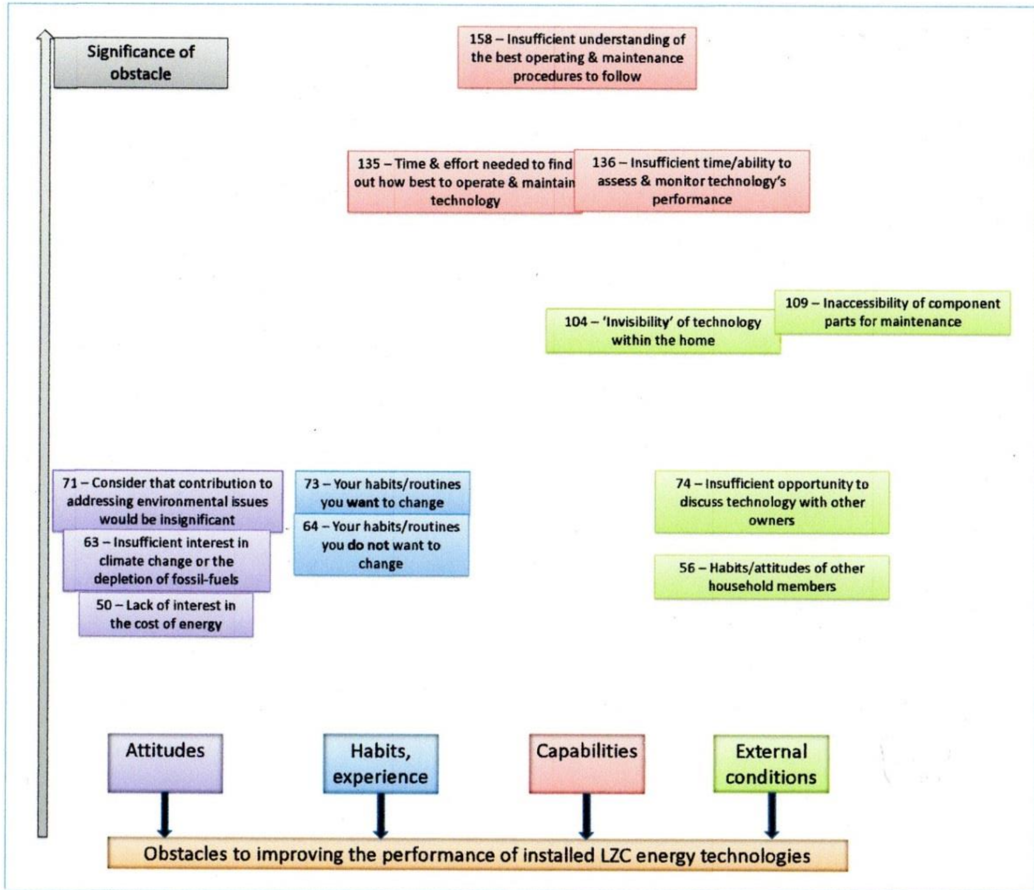


Figure 1. Characterisation of the obstacles to improving the performance of installed LZC energy technologies (adapted from Wilson & Dowlatabadi, 2007, p.183)

Characterising the obstacles to improved performance
This diagram has weighted the responses from householders relating to the significance attached to various obstacles (refer to the box below for details) and characterised them into the following four categories:

- Attitudes
- Habits & experience
- Capabilities
- External conditions

The diagram illustrates that the most significant category of obstacles are those that relate to the self-assessed capabilities of householders. The second most significant category of obstacles relate to conditions external to the individual responding, in particular the way the LZC energy technology and the associated controls are arranged within the home.

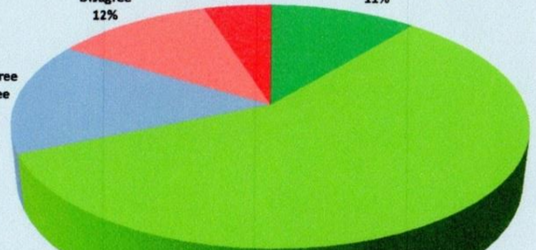
How were the numbers alongside each obstacle calculated?
In the top left hand corner of the obstacle boxes is a number which represents the significance of each obstacle (for the illustrative purposes of this diagram). This is a 'weighted' total which was calculated in the following way:

Weighted total = (3 x Number of householders who rated the obstacle as extremely significant)
+ (2 x Number of householders who rated the obstacle as very significant)
+ (1 x Number of householders who rated the obstacle as somewhat significant)

Thus the weighting attached to a response is proportional to the significance given to that obstacle. If the obstacle was rated as 'not very' or 'not at all' significant in a response, it was not included in this weighted total.

Do householders understand how their household practices may impact on the benefits gained from their LZC energy technology?

Figure 1. Responses to the statement: 'You understand how your household practices may impact on the benefits gained from your LZC energy technology'



Overall response
Participants in the survey were asked to assess whether they understood how their household practices might impact on the benefits gained from their installed LZC energy technology. Figure 1 summarises the results of this self-assessment exercise. The majority of participants (68%) consider that they do understand how their household practices may impact on the benefits gained from their LZC energy technology, whilst only 17% consider that they do not.

Individual responses (continued)
Other householders mention changes in routines and behaviours that do not relate directly to the use of their LZC energy technologies but indicate a raised level of action to reduce energy consumption around the home, or a raised level of awareness on related issues:

- "Be smarter about usage, turning appliances off and radiators down etc."
- "More aware of the potential benefits of changes – capital cost versus potential benefits."
- "Think about energy consumption of appliances and insulation/heat loss in our house."
- " ... more cautious as we measure consumption now."

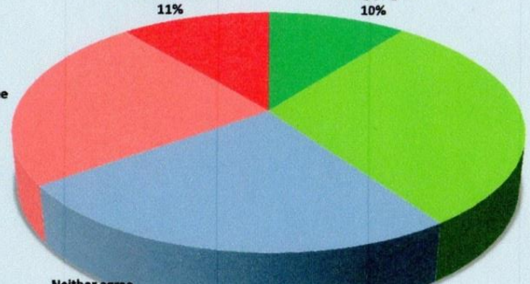
One householder has altered her behaviour to compensate for recurrent leaks from her solar thermal system:

- "Keep a watchful eye open for water leaks". "[When going out] I would turn off LZC wherever possible due to [leaks]."

Has the presence of LZC energy technologies caused householders to do things differently *inside* their homes?

Overall response
In order to obtain an assessment on what proportion of new LZC energy technology users have changed their household practices, participants in the survey were asked whether the presence of the LZC energy technology had caused them to do things differently *inside* their home. 40% of participants agreed or strongly agreed that changes had occurred, whilst 35% did not (Figure 2). The remaining 25% neither agreed nor disagreed that things were being done differently.

Figure 2. Responses to the statement: 'The presence of your LZC energy technology has caused you to do things differently *inside* your home'



Individual responses
Participants that agreed the technology had caused them to do things differently were asked to provide examples. Most of these examples relate directly to optimising the benefits gained from solar thermal technology:

- "Trying to put washing on during the day and not in the evening, can't do that with dishwasher as it hasn't got a time delay." [PV & solar thermal user]
- "Use of hot water – I'm more aware of the temperature of the water, whether it's heated up during the day and whether I need to use the electric heater."

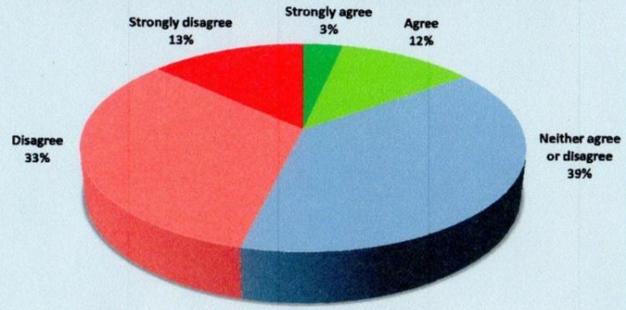
- "Reduce amount of time hot water [is] on during summer months."
- "I might consider showering later in the day if it's sunny."
- "Switch off gas boiler from April to October."
- "Changing times we shower to take advantage of the solar heating (afternoon/evening)."

In other examples, from air source heat pump users, the changes in routine were made to improve the comfort levels provided by the technology:

- "Heating timing patterns have changed to keep house warm in winter."
- "Heating is set to permanently low setting. Controlled by outdoor thermostat."

Has the presence of LZC energy technologies led householders to behave differently *away from* their homes due to an increased environmental awareness?

Figure 1. Responses to the statement: 'The presence of your LZC energy technology has led you to behaving differently *away from* your home due to an increased environmental awareness'



Overall response
15% of householders agree or strongly agree that the presence of their LZC energy technology has led them to behave differently *away from* their homes (Figure 1). 46% disagree or strongly disagree that this is the case and the remaining 39% of householders hold a neutral position on this statement.

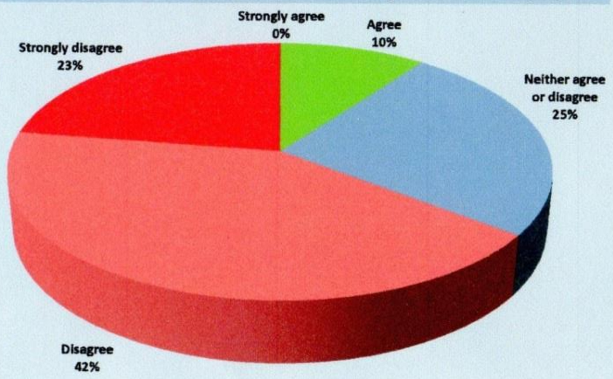
Participants that agreed the technology had caused them to behave differently were asked to provide examples.

Individual responses
- "Drive more efficiently, use less heating & turning lights off – but mainly due to cost savings."
- "Do one car journey rather than several per day."
- "I go by bus where I can."
- "More recycling – checking diesel use in car for efficiency – much economy related."
- "Shopping for appliances, energy supplier."
- "More eco-friendly like reusable bags, cars with better mileage and recycling."
- "More conscious of recycling, low energy options, minimising transport etc."

Individual responses
- "Considering installing several types of LZC technologies in new property on a savings versus capital cost basis."
- "It has increased my awareness of hidden agendas behind 'eco' products and made me increasingly wary of them."
- "When I purchased a new car 18 months ago CO_2 [carbon dioxide] emissions were a key factor in my decision."
- "Selling older cars, buying new build."

Has the presence of LZC energy technologies led householders to get involved with new activities *outside of* the home or with new people?

Figure 2. Responses to the statement: 'The presence of your LZC energy technology has led you to get involved with new activities *outside of* the home or new people'



Overall response
Only 10% of householders agree that the presence of their LZC energy technology has led them to get involved with new activities *outside of* the home or with new people (Figure 2). The majority of householders (65%) disagree or strongly disagree with this statement and the remaining 25% of householders hold a neutral position.

In response to this question, a few householders have given examples of technology-related conversations held with neighbours (who may or may not have become acquaintances without the presence of the LZC energy technology).

Individual responses
- "Spoke to neighbour who has solar panels to see if our system was producing similar results to theirs"
- "Asking neighbours how the system works"
- "Neighbours have common complaints about the systems"
- "Generally more aware and using [knowledge] in professional work"
- "A lot of people have asked about it & looked into schemes to install it" [Air source heat pump is located by front door.]

The role of residents' associations
In a number of the developments studied, residents' associations have been set up.

One of the questions addressed within the interviews is the extent to which these residents' associations act as forums in which the maintenance and operation of the technologies is discussed between residents, and best practices established.

Those interviewed to date, report that their residents' associations have not actively taken on this role where the LZC energy technologies serve individual dwellings.

Appendix 15 - First exhibition - feedback sheet for householders

What has been the impact of this research on you so far?

Your feedback would be greatly appreciated on the following questions which relate to your installed low and zero carbon energy technologies:

1. What have you learnt from reflecting on your own practices and experiences, and on learning about others' practices and experiences?
2. Has your involvement with this research reinforced your existing practices or caused you to question what you do or do not do?
3. What is your overall impression of the early research results?
4. Has the research project been useful or helpful so far?

Please write your responses on one of the sheets provided and put it in the box below, along with any other comments or suggestions you may have.

Many thanks

Appendix 16 - Provisional agenda - Household Support Network launch (April 2012)

Time	Topic/action	Materials
	Change door sign Separate sheet stuck on spare flipchart stand for additional items Attach 2 obstacle posters to spare flipchart stands	Clock, string, scissors, camera, name label, flipchart x 3, 2x boarded posters, other A1 posters, map, business cards, bottle of water, writing pad, list of those that might come
	Arrange chairs	Crescent shape with flipcharts in opening
	Offer tea/coffee	
3.10	**Pass round contact information sheet**	Contact information sheet & flipboard Switch 2 x DM-20 recorders on
3.10	**Ask to put on name & technology labels**	White rectangular labels & coloured dots Key to dots
	Open flipchart 1 & show proposed agenda	
3.15	**Introduce myself** **Let me know if you can't hear me or if I am going too fast or not making any sense.** **Talk about audio recording** • Removes the need to rely on potentially faulty recollections & inadequate note taking on my part • Enables me to listen better and facilitate the meeting better as opposed to just taking notes Recording will be used to produce minutes of meeting and for contributing to the research more generally.	

	Ask for thoughts on what rules the meetings should abide by	Have list of possible ground rules: - Confidentiality - Respect - Non-judgemental ('sensitive to the different attitudes, motivations, understanding, tolerances and capacities of individuals in the group')
3.17	**Summarise overview for this first meeting:** **I've put together a provisional agenda for the meeting, which I'll briefly run through. I'll then check to see what else you might want to gain from the meeting** • Who we all are? • Why conduct this research? • How has the research affected you so far? • What were the main identified incentives & obstacles to optimising the performance of the LZC energy technologies? • What were your motivations for joining the group & what are you hoping to gain from being part of this network? • What objectives shall we set for the network? • What should the network do first? **Is there anything else anyone would like to gain from this first meeting?**	Write up first on flipchart 1

3.19	**Who we all are?** **Introduce in turn: Name, technology type, one positive aspect of technology & one negative aspect:** • Round robin	Write up on flipchart 2 & 3 – • Technology type & positive aspect (2)green • Technology type & negative aspect (3) red
	Ask whether anyone knows anyone else already	
	Apologies for absence	
3.30	**Why conduct this research?** **Brief overview of local planning LZC target, the future concept of zero-carbon homes & main objectives of research:** • Merton Rule 2003 & Woking's interpretation 2005/6 – differences • Reduce carbon dioxide emissions in response to the threat of climate change, tackle fuel poverty, improve energy security, reduce reliance on non-renewable fossil fuels • Government's policy of achieving 'zero-carbon' new homes by 2016 • Extent to which low carbon and renewable energy technologies are designed into new homes is set to increase significantly. • Important to learn *now* from the experiences of existing users of these technologies, such as yourselves.	

	Overall, this research will investigate: • how such technologies are used in practice and what experiences occupants have regarding these new forms of technology; • whether these low carbon and renewable energy technologies are likely to deliver the carbon dioxide reductions envisaged & the generation of energy envisaged; • how the design/installation/use of these energy technologies can be improved; and • whether interventions/support may be required to improve upon the existing situation.	Emphasise worth of research: - support from Woking Council – provision of information & venues for interviews, want to know the results - research award from Royal Geographical Society
3.35	**How has the research affected you so far?** Joint reflection **Ask for feedback from engagement with research:** • **Questionnaires** • **Interviews** • **Summary of results as posted** • **Exhibition** What have you gained from reflecting on your own practices & experiences and on learning about others' practices & experiences? Has your engagement with this research reinforced your existing behaviour or caused you to question what you do or don't do?	**Hand-out cards & pens** Give a moment to write ideas down on card Then ask each in turn Write up on flipchart 2 – provides an assessment of impact of research so far.

	Hand-out cards & pens Give a moment to write ideas down on card Then will ask each in turn to feedback what they have written **Could then ask** What is your overall impression of the early research results? Has the research project been useful or helpful so far?	
3.45	**Review incentives & obstacles to optimising performance of technologies** This second diagram has weighted the responses from householders relating to the significance attached to various obstacles and characterised them into the following four categories: • Attitudes • Habits & experience • Capabilities • External conditions The diagram illustrates that the most significant category of obstacles are those that relate to the self-assessed capabilities of householders. The second most significant category of obstacles relate to conditions external to the individual responding, in particular the way the LZC energy technology and the associated controls are arranged within the home. **Mention examples of these obstacles that could be addressed by the network**	Look at 2 posters on this
	Any feedback on these results – any surprises?	

	Any feedback on the exhibition results more generally?	
	Mention the forthcoming repeat of the exhibition for planners, developers, architects etc	**List of those invited to 2nd exhibition** Date & possibly number of visitors invited Demonstrate the 'impact of the group's efforts, helping to maintain and enhance motivation and interest'
	Who would they like to provide feedback to?	Prepare list of developers , installers, management companies & manufacturers Circulate list for people to add to it with further suggestions
3.50	**Introduction to the overarching objective for the network & action research** To help householders optimise the performance of their LZC energy technologies.	Refer back to incentives poster
3.52	**What were your motivations for joining this group & what are you hoping to gain from being part of this network:** **- Round-robin** **- Write down points (repeats allowed – create tally)** **- Summarise** Put in groups if enough people Can refine/add to this as we go	Write motivations up on flipchart 2, e.g. • a social network, • the provision of training, • learning more about their own and the other types of technologies, • assistance with trouble-shooting/collective maintenance arrangements, • assisting other users of LZC energy technologies, • providing feedback to developers, planners, architects, installers.

4.05	**What objectives shall we set for the network?** **What do you think it could achieve?** **Develop action plan** **- Turn peoples' expectations of the network into objectives** Ask members to suggest key objectives How is the network going to deliver the objectives (including timescales and responsibilities)? Could prioritise, look for quick win objectives.	Write objectives up on other flipchart 3
	Monitoring of impacts	
	Establish skill & knowledge that participants can contribute	Make use of available skills & promote engagement. Cater for different levels of engagement
4.15	**Ask for suggestions on what the next few meetings should entail.** **Any actions to undertake before the next meeting** e.g. review maintenance schedule recommended for installed technologies	Write up ideas on flipchart 2.
4.18	**Establish frequency, timing & length of meetings**	Every 2 weeks? Every month?
4.25	**Comments/reflection on this first network meeting**	

<u>Possible actions, objectives & roles for the householder support network</u>
Seeking information
Best practice guidance/ checklist of desired user behaviour from suppliers/manufacturers/advisory groups (e.g. Energy Saving Trust)
Talks by technology representatives/installers
Talk by planners/building control/climate change policy officer etc
One-to-one training
Find out difference between as-designed energy demand and actual energy demand: one-to-one case studies
Find out actual sizing of technology compared to that expected from SAP assessments & the renewable energy assessment
Sharing experiences & seeking assistance
Comparing practices – benchmarking, establishing best practice amongst members
Exchanging knowledge
Developing a community of local LZC energy technology users
Trouble-shooting
Maintenance
Collective maintenance agreements/arrangements
Look at recommended service intervals for the different technologies
Can anything invalidate the warranty of the equipment?

Self-rating of performance and change
How do users rate themselves against how well they and their technology is performing against ideal operating & maintenance criteria
Assess level of change that has occurred through living with the technologies
Assess further scope for change
Addressing barriers to further change
Design intervention strategies to address the parts of the overall system that are creating barriers to further change
Trial improved ways of operating the technology
Feedback to relevant organisations (provide feedback loop)
Evaluate effectiveness of policies/designs: - usability/reliability/level of understanding of technology - actual performance of technology versus targets - feedback on any issues relating to the configuration of technologies in the home
Available for consultation, trials etc.
Lobbying on any identified issues
Narratives/learning histories relating to the technologies (written or recorded) could provide indirect feedback to those interested. For example: How did users come to integrate, interact with & attend to the technologies? How are the technologies being used now? What have users learnt & what do they identify as still needing to learn? Could act as a resource to planners, developers, other users – to initiate debate, reflection etc

Source of experience
Information point for potential users
Social forum
E-mail list
Blog?

Appendix 17 - Second exhibition - invitation to organisations

How are occupants of new homes engaging with installed low carbon and renewable energy technologies?

Come and view a display of recent research results obtained from a project underway in the Woking borough. This display summarises the views and experiences of 120 occupants of new homes constructed with various low carbon and renewable energy technologies.

Find out whether householders:

- **are satisfied with the performance of their low carbon/renewable technologies**
- **consider that they have been given sufficient information on how to operate and maintain these technologies**
- **have altered any household practices because of their low carbon/ renewable technologies**

Find out also what householders regard as the main *incentives* and *obstacles* to improving the performance of their energy technologies further.

When: **Monday 14th May 2012, drop-in anytime between 12 noon and 2pm.**

Where: **Committee Room 2, Civic Offices, Woking Council, Woking, Surrey, GU21 6YL [www.woking.gov.uk/woking/maps/directionscivicoffices] Please sign-in at reception on arrival.**

Who: **This event should be of interest to any professional involved with the policy, planning, design, construction and management of new homes. It should also interest those involved in the design, installation and maintenance of low carbon and renewable energy technologies.**

How: **To register for this free event, or to find out more, please send an e-mail to lise.andreassen.2010@live.rhul.ac.uk. Please circulate this invitation within your organisation and to your colleagues.**

This research is being undertaken by Lise Andreassen at Royal Holloway, University of London. She will be available at the event to discuss the research results.

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Appendix 18 - Second exhibition - posters displayed

Department of Geography

Optimising low and zero carbon energy technologies in new homes

Lise Andreassen

Royal Holloway University of London

Royal Geographical Society with IBG
Advancing geography and geographical learning

Background to this exhibition

Given the Government's policy of achieving 'zero-carbon' new homes by 2016, the extent to which low carbon and renewable energy technologies are designed into new homes is set to increase significantly. So it is especially important to learn *now* from the experiences of existing users of these technologies and to feedback the findings to relevant professionals, such as yourself. Overall, this research will investigate:

- how such technologies are used in practice and what experiences occupants have regarding these new forms of technology;
- whether these low carbon and renewable energy technologies are likely to deliver the carbon dioxide reductions envisaged; and
- how the design/installation/use of these energy technologies can be improved.

Initial research results have been fed back to those local residents that participated in the research and to other local occupants of new homes with low carbon and renewable energy technologies installed.

The borough of Woking was selected for the research as it has a large number of new homes built with installed low and zero carbon (LZC) energy technologies. All occupants of these new homes (as identified) have been invited to participate in this borough-wide research project.

This exhibition is based mainly on the results from the first phase of this research.

The main objectives for the overall research project are as follows:

Objective 1
To conduct a post-occupancy evaluation of the drivers and barriers that affect householder behaviour in relation to optimising installed LZC energy technologies in new homes.

Objective 2
To assess the wider effects of LZC energy technologies on users and others (e.g. what 'spill-over' effects on seemingly unconnected activities and behaviours have the technologies led to?).

Objective 3
To initiate the participatory creation of a borough-wide, householder support network to promote improvements in the installation and usage of LZC energy technologies.

The main objectives of this exhibition are:

- **To provide feedback on householder experiences to those involved with the policy, planning, design, construction and management of new homes**
- **To provide feedback on householder experiences to those involved in the design, installation and maintenance of low carbon and renewable energy technologies**
- **To invite you to act on what you learn, where relevant**

The research project is comprised of three phases:

Phase 1 (completed)
The initial phase of the research, undertaken between October 2011 and January 2012, consisted of a questionnaire that was distributed to all new homes (as identified) that had been granted planning permission in the borough of Woking since 2005. 120 occupants participated in this survey of householders' experiences with installed LZC energy technologies.

Phase 2 (in progress)
The second phase of the research, which commenced in February 2012, entails 1-hour interviews. The aim is to obtain a selection of more detailed accounts of householders' experiences with LZC energy technologies.

Phase 3 (starting)
The third phase of the research involves the setting up and running of a householder support network, which aims to promote improvements in the installation and usage of LZC energy technologies.

Members of this network will be able collectively to decide what aims the network should have (e.g. as a social network, the provision of training, assistance with trouble-shooting).

If you would like to host this exhibition at your organisation for the benefit of your work colleagues, send an e-mail to lise.andreassen.2010@live.rhul.ac.uk

This project was supported by the Royal Geographical Society (with the Institute of British Geographers) with a Postgraduate Research Award

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Which low and zero carbon (LZC) energy technologies are installed?

The number of new homes with installed LZC energy technologies
Over 1000 occupants of new homes, within the borough of Woking, were asked to complete a questionnaire relating to any LZC energy technologies that had been installed by the developer in their home. The questionnaires were distributed between October 2011 and January 2012. From the feedback received, it is estimated that approximately 670 of these new homes have actually been equipped with or are served internally (e.g. via a communal heating system) by some form of this technology. It is the households in these homes that form the focus for this research.

The remainder of the new homes surveyed are not served, within the home, by any form of LZC energy technology for a variety of reasons, such as:

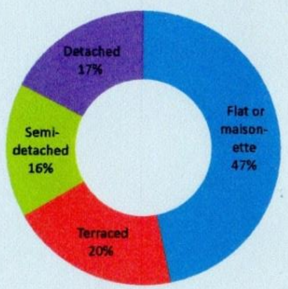
- The LZC energy technology installed serves communal facilities only;
- The LZC energy technology is concentrated in other homes within the development;
- The developer commenced but did not complete the installation of the LZC energy technology.

Types of LZC energy technologies installed
The LZC energy technologies which these householders identified as being installed are summarised below in Figure 3. Solar thermal systems, which provide hot water, are the predominant type of LZC energy technology, and have been installed by developers in 60% of the participating householders' homes. The next most frequent technologies installed are combined heat & power systems, air source heat pumps, mechanical ventilation & heat recovery systems and communal biomass systems, each present in 10% - 16% of households.

25 of the 120 participating households have more than one type of LZC energy technology installed.

From conversations held, it appears that householders are not always aware when there is a mechanical ventilation and heat recovery system installed in their home. In other instances, there may be some confusion as to what type of system they actually have installed (e.g. does the solar panel provide hot water or electricity?). For these reasons, the data shown in Figure 3 may not be entirely accurate.

Figure 1. Dwelling type



Response rate
120 of the targeted households completed and returned the survey questionnaire, which represented nearly an 18% return rate.

Dwelling type
The mix of dwelling types occupied by the participating householders are summarised in Figure 1.
47% of participants have moved into new flats. Most householders have been living in their new homes for 2 or less years (refer to Figure 2).

Figure 2. Length of time in home

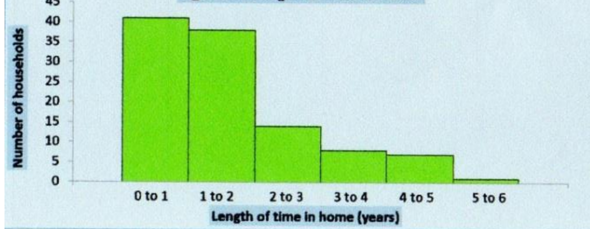
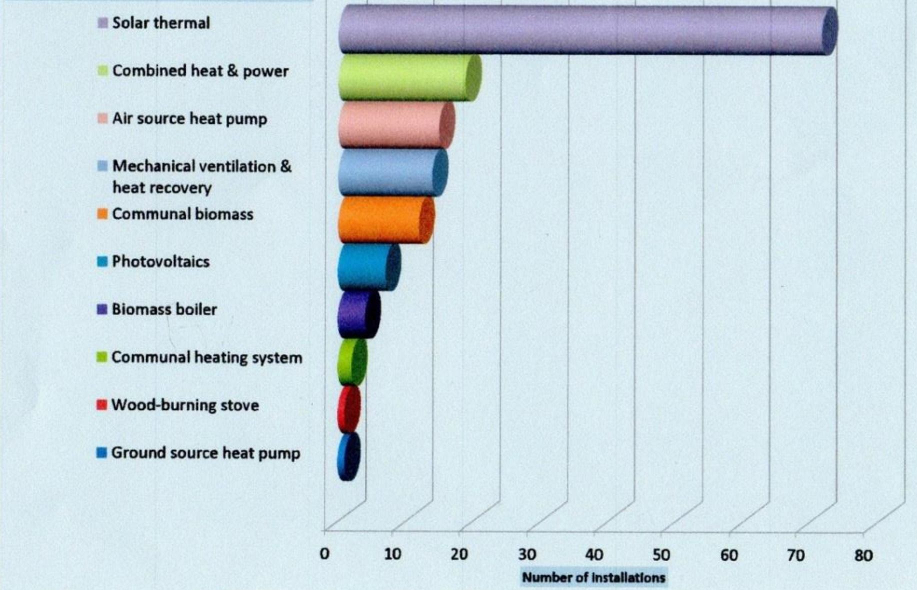
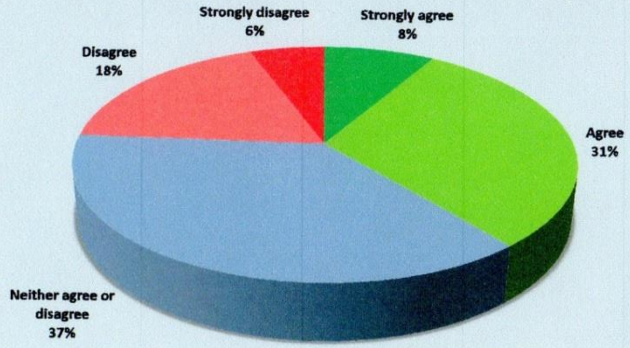


Figure 3. Type of LZC energy technology installed



Is the presence of low and zero carbon (LZC) energy technologies a positive influence on householders when selecting a new home?

Figure 1. Responses to the statement: 'The presence of the LZC energy technology was a positive influence on your choice to live in your home'



Overall response

39% of householders agree or strongly agree that the presence of the LZC energy technology in their home had a positive influence on them selecting that property to live in (Figure 1). 24% disagree or strongly disagree that this was the case and the remaining 37% of householders hold a neutral position on this statement.

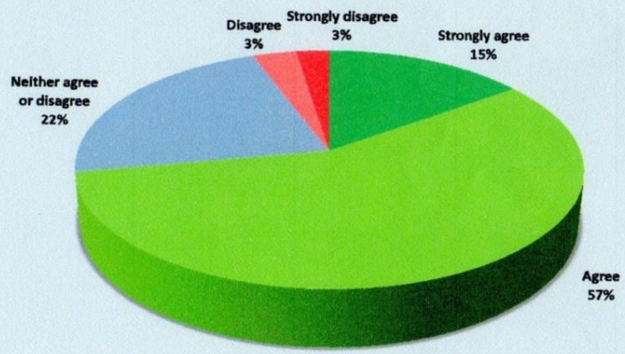
From comments made on the returned questionnaires and from conversations held with occupants of these new homes, it is apparent that the LZC energy technology is, in certain cases, not a feature that is drawn attention to by those marketing the properties for sale or rent.

Individual responses

- "Until I received this questionnaire, I was not aware of the LZC in my house. I do care about the environment, but have not read through the literature provided by my landlord – I rent the property."
- "... we did not buy the apartment for its propensity to save the world from greenhouse gases but rather to save ourselves from huge fuel bills. Our motives were and remain wholly selfish."
- "Although I am interested in LZC to save money and polar bears, the flat comes with district heating – [it] wasn't a factor in my decision."
- "The CHP [combined heat & power system] did not affect my choice of purchase."

Are people interested in how their LZC energy technology works and what effects its performance level?

Figure 2. Responses to the statement: 'You are interested in the ways your LZC energy technology works and what effects its performance levels'



Overall response

Although only 39% of householders considered that the LZC energy technology was a positive influence on them selecting their property, Figure 2 shows that 72% are interested in the ways in which their technology works and what effects its performance levels. Only 6% disagree or strongly disagree with this statement and the remaining 22% of householders hold a neutral position.

As referred to on another poster (Number 7), reducing energy costs is the most significant incentive for householders to improve the performance of their LZC energy technology i.e. people are particularly interested in the performance of their technology and how it works because they wish to maximise their cost savings.

Difficulty in comparing energy costs

A number of householders have made the comment that it is difficult to know whether they are spending less on energy now than if they had only conventional heating systems installed. This uncertainty arises as householders have often moved into a different size and age of property, and thus they do not have a similar situation to compare their current energy costs with.

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How satisfied are householders with the performance of their low and zero carbon (LZC) energy technologies?

Comments by solar thermal users

- "The system works so well and very effective so less energy."
- "Solar water heating reduced my gas bill to less than £40 for the summer (incl. standing charge)."
- "It works well but at the cost of £4000 it does not pay back – either ground source or air source heat pumps would be more efficient. One of the panels leaked – and could be prone to high maintenance costs."
- "I am probably not the best person to ask about this as I have little interest in saving a few ££s (fortunately)."
- "The solar panel we have does little to reduce impact on the environment as it only works when the day is sunny!!"
- "Solar panels are totally useless in this country – the manufacturer said we need at least 3-4 days of at least 28° C in order to get enough hot water."
- "It's useless – seems to generate very little slightly warmed water" "It is rubbish – advert says "free piping hot water" – barely warms to 30°C."
- "I have experienced 2 major leaks from the system causing ceilings to collapse and other owners have had problems. The system is currently isolated and I would happily strip it out to give more useful storage space."

Comments by air source heat pump (ASHP) users

- "The house is electricity only. The cost of running it using air source heat pump is greatly reduced.'
- "Air source heat pump consumes vast amounts of electricity and I have since discovered this should be fitted only in conjunction with solar PV [photovoltaic] panels, to offset electricity consumption."
- Last winter, one householder had trouble with their ASHP unit. The 1st and 2nd floors were warm enough but not the downstairs, so they had to buy extra heaters. They had not been told properly how the ASHP works. They have under-floor heating throughout and miss having radiators.
- One householder stated she was not happy with her ASHP.
- Another householder called his ASHP 'horrendous'.

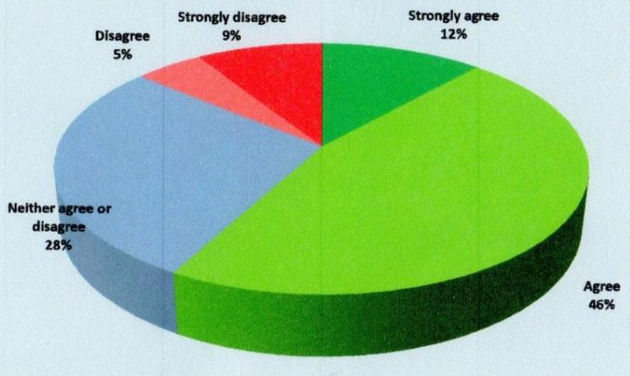
Overall response

58% of householders agree or strongly agree that they are satisfied with the performance of their LZC energy technologies (Figure 1). Only 14% disagree or strongly disagree with the statement that they are satisfied and the remaining 28% of householders hold a neutral position on this.

Individual responses

The comments made by householders have been segregated by technology type into the 5 other text boxes on this poster. Some comments were obtained from doorstep conversations from people who did not subsequently return completed questionnaires.

Figure 1. Responses to the statement: 'You are satisfied with the performance of your LZC energy technology'



Comments by combined heat & power (CHP) users

- "There's an automatic temperature control system built in flat. So far I've never changed the settings or had any problems. So the entire system is almost transparent to me – and it is quite comfortable."
- "Downside to CHP is that I don't like being locked into one supplier of energy. It is anti-competitive."

Comments by mechanical ventilation & heat recovery (MVHR) users

- "Noisy to run, no temperature difference when ran."
- One householder who has a MVHR system has not noticed any benefits from running it.

Comments by combined CHP/biomass/gas system users

- "The biomass boiler is totally useless – so expensive it is unusable – has to be switched on twice yearly to satisfy rules. Makes a total nonsense of any attempt to save energy and extremely demotivating."
- "[The developer & energy contractors] offered us a "unique monitoring system" which was so innovative it would read the heat meters from outside our property. The only innovation here is that it isn't going to happen. We were told that the HIU [hydraulic interface unit] controls are pre-set and we were instructed: DO NOT ADJUST ANY OF THESE CONTROLS. We were personally instructed not to open the cabinet. Six months later, all of this has changed. There will be no remote monitoring and we must open the cabinet and read our own, quite meaningless figures. Because the water heating settings were maximised at 'tepid', we were shown how to turn the whole thing up manually for 'normal living'."
- One householder does not believe they should be paying more for their energy provision in order to reduce carbon dioxide emissions.
- "It was installed purely for planning permission [i.e. CHP & biomass boiler] and provides residents with very little benefits, and actually costs us more than a conventional heating system due to the high maintenance costs."
- "... the biomass boiler and CHP still have not been activated/commissioned. We, the residents, are very frustrated. The commissioning appears to be in the hands of the management company ..."
- "In our apartments we have had issues with our energy system as the developer installed it to meet planning regulations but grossly underestimated the running costs."

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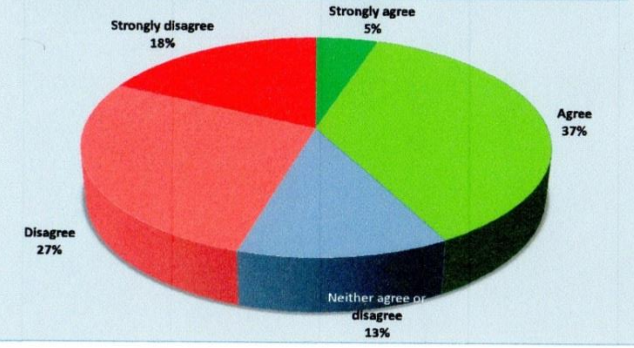
Do householders consider that the developer or landlord has provided them with sufficient information on operating and maintaining their LZC energy technology?

Overall response
42% of householders agree or strongly agree that their developer (or landlord) has provided them with sufficient information on how to operate and maintain their LZC energy technology (Figure 1). However, a slightly higher proportion of householders , at 45%, disagree or strongly disagree that sufficient information was provided.

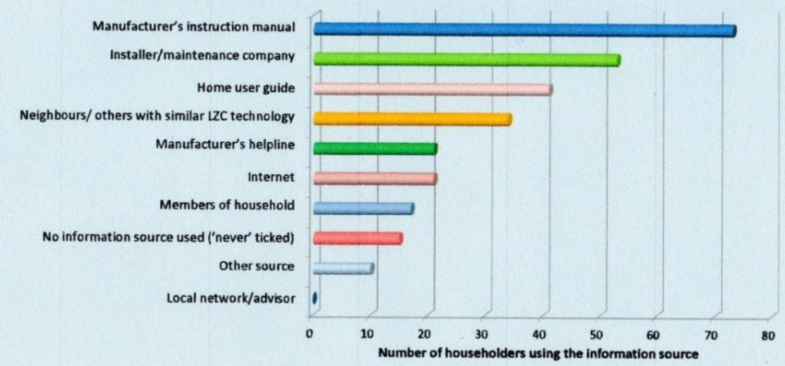
Figure 1. Responses to the statement: 'The developer or landlord has provided you with sufficient information on operating and maintaining your LZC energy technology'



Individual responses

- "Solar panels were provided with the house – we have been given no documentation for the system!!"
- "Information supplied with house was very vague & aimed at installers not users – we also had to request it!"
- "No information at all."
- "When moving into this new flat, we had very little information given to us. The manager is of little use."
- "Developers are rewarded for installing such devices, but they should also be required to provide sufficient training/ documentation on their use."
- One householder stated that there is something in the loft, but she is not sure what it is. She does not think it is switched on. She moved in after tenants had been living there. The place had been cleared and there was no information given to them on the house. [Neighbouring properties have mechanical ventilation & heat recovery (MVHR) systems.]
- Another householder stated that there may have been a sheet of information on the MVHR system at the time of moving in but she does not remember reading anything. There was no training given on how to operate the system. When sales people came round to show them how to open and close the windows, they did not mention the MVHR system. The extraction points are in the first floor ceiling by the stairwell and in the bathroom and shower room.

Figure 2. Which sources of information do householders use to help them maximise the performance of and benefits from their LZC energy technology?



Where do householders obtain their information from?
Given that 45% of householders disagree or strongly disagree that sufficient information was provided by their developer or landlord, which other sources of information do they turn to for assistance?

Figure 2 indicates that in addition to using the manufacturer's instruction manual and home user guide, information is commonly obtained from the installer of the technology and also neighbours with similar LZC energy technologies installed.

15 householders (representing 12% of those surveyed) stated that they have never sought out information that might help them maximise the performance of their LZC energy technology. In 3 of these cases, the LZC energy technology consisted of a communal system overseen by a management company.

To what degree are the LZC energy technologies maintained?
The degree to which installed technologies are maintained, is currently being explored in Phase 2 of the research. Of the 23 people interviewed to date, not one has been proactively approached by service providers (e.g. installers, manufacturers) in order to arrange for the servicing of their LZC energy technologies.

Service contracts (e.g. annual servicing) are not typically in place, except for communal heating and power systems. One or two householders have tried to arrange for service contracts, but have found an unwillingness on the side of the installers/manufacturers to enter into such arrangements.

One householder maintains the installed solar thermal system himself. Others only tend to have their systems checked when they believe there is a fault with it (as indicated by an abnormal noise, a leak, a suspected drop in performance etc.).

In summary, the degree to which the technologies are maintained is typically very limited and irregular.

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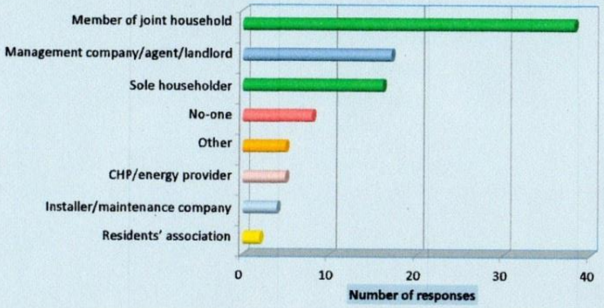
Who ensures that the LZC energy technology is operating efficiently and is maintained as necessary?

Figure 1. Who ensures that the LZC energy technology is operating efficiently and is maintained as necessary?



Overall response
In 57% of new homes, someone within the household is identified as having the responsibility for ensuring the LZC energy technology is operating efficiently and is maintained as required. In other cases, an external organisation is allocated this role, such as the management company or landlord. In 8% of households, there is no-one taking on this responsibility.

Individual responses
"Cost of annual maintenance reduces the benefits to ourselves."
"No idea how to maintain."
"I am only occupant and don't bother."

Figure 2. Within joint households (where relevant), who ensures that the LZC energy technology is operating efficiently and is maintained as necessary?

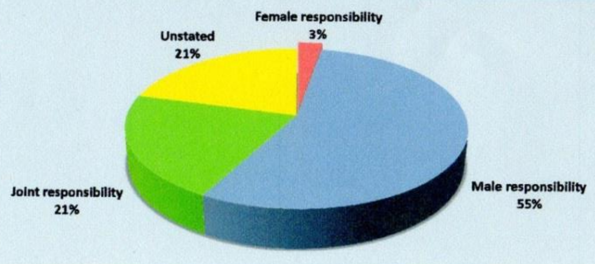
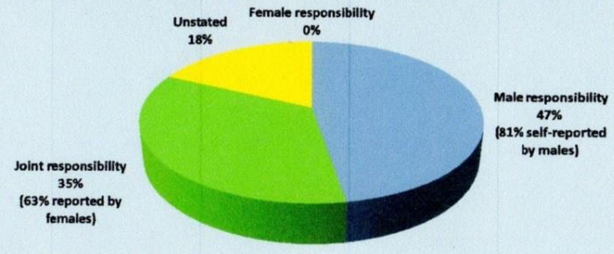


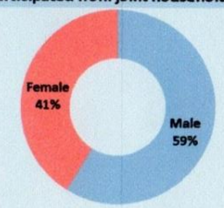
Figure 3. Within joint households, who has the main responsibility for making sure that day-to-day practices in the home make the most of the energy produced?



Where does the responsibility lie within households?
Figure 2 illustrates that within joint households, the responsibility for ensuring that the LZC energy technology is working efficiently is stated as resting predominantly with a male member of the household (55% of cases) or is shared jointly amongst the adults (21% of cases).

Similarly, when it comes to ensuring that a household's day-to-day practices make the most of the energy produced by the LZC energy technology, it is stated as being mainly the responsibility of a male member of the household (47%) or as being jointly shared amongst the adults (35%) (refer to Figure 3).

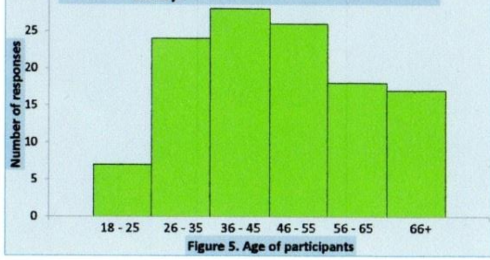
Figure 4. What gender are those that participated from joint households?



Age and gender of participants
As shown in Figure 4, men were responsible for completing 59% of the questionnaires from joint households.

The age distribution of all those that participated in the survey (i.e. from single and joint households) is illustrated in Figure 5.

Figure 5. What age are those that participated in the survey?



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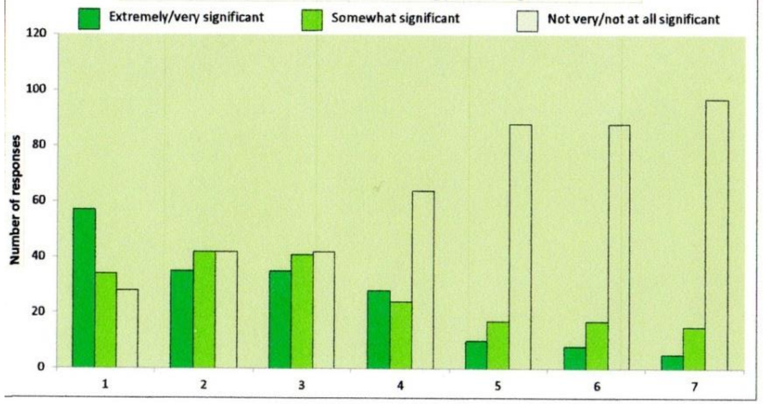
What do householders regard as the main *incentives* for improving the performance of their LZC energy technology?

Figure 1. How significant have certain *incentives* been for improving the performance of installed LZC energy technologies?



Incentives ranked in __decreasing__ order of significance

1. Reducing energy costs
2. Reducing carbon dioxide emissions
3. Reducing demands on non-renewable fossil fuels (i.e. oil, natural gas, coal)
4. Producing more of your own energy
5. Pleasing particular household members
6. Interacting with and gaining feedback from display monitors and meters
7. Demonstrating success to others outside of your household

Additional incentives mentioned by householders

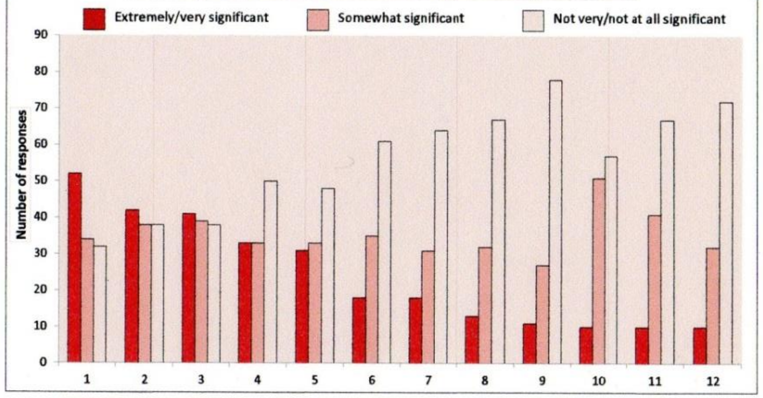
- "Making the house more comfortable"
- "Optimising efficiency"

Additional obstacles mentioned by householders

- "Unreliability"
- "The cost of LZC and the lack of efficiency."
- "Householder is 96 and has needed much support from a variety of people."
- "Developer who installed it did it to get planning permission & is not interested in it."
- "No way of knowing if it is effective, as energy bills are still high."

What do householders regard as the main *obstacles* to improving the performance of their LZC energy technology?

Figure 2. How significant have certain *obstacles* been to improving the performance of installed LZC energy technology?



Obstacles ranked in __decreasing__ order of significance

1. An insufficient understanding of the best operating and maintenance procedures to follow for the LZC energy technology
2. Insufficient time/ability to assess and monitor the technology's performance levels
3. The time and effort needed to find out how best to operate and maintain the LZC energy technology
4. The inaccessibility of component parts of the LZC energy technology for maintenance etc.
5. The 'invisibility' of the LZC energy technology within the home
6. Insufficient opportunity to discuss your LZC energy technology with other owners
7. You consider that your contribution to addressing these environmental concerns would be too insignificant to bother about
8. An insufficient interest in climate change or the depletion of non-renewable fossil fuels
9. A lack of interest in the cost of energy
10. Your personal routines/habits within the home that you **do** want to change
11. Your personal routines/habits within the home that you **do not** want to change
12. The routines, habits and attitudes of other members of your household

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Characterising the obstacles to improved performance of LZC energy technologies

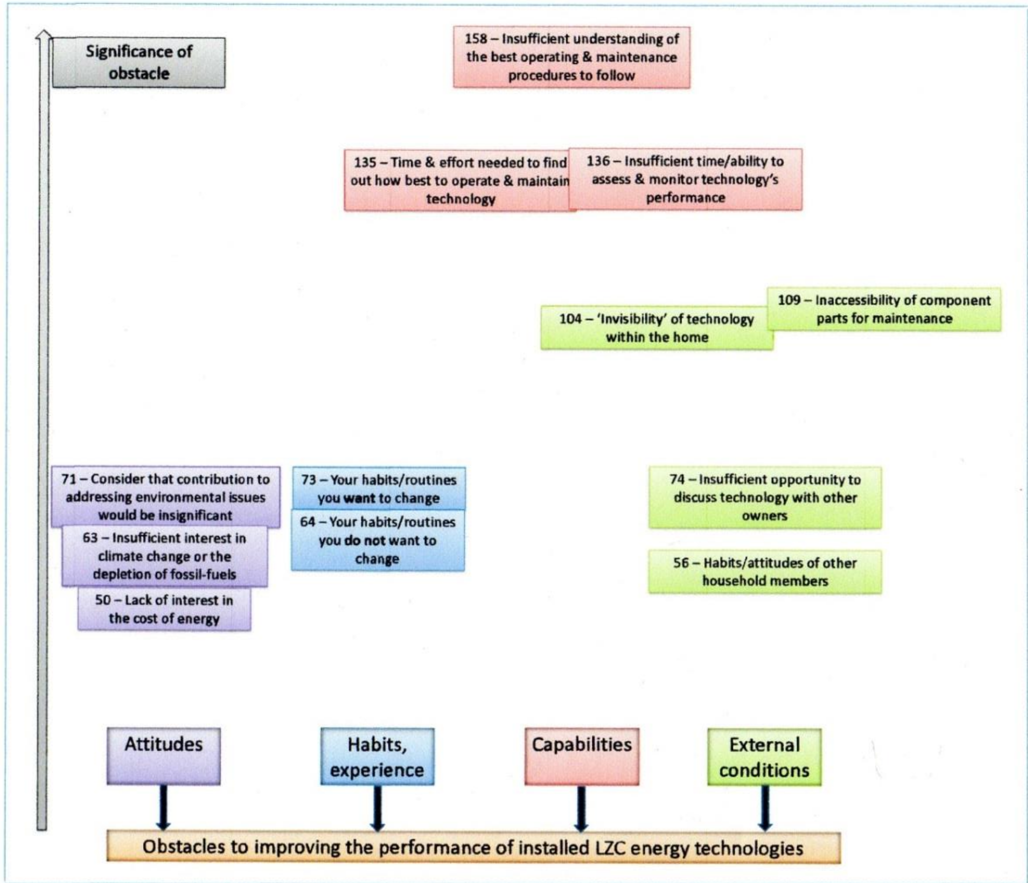

Figure 1. Characterisation of the obstacles to improving the performance of installed LZC energy technologies (adapted from Wilson & Dowlatabadi, 2007, p.183)

Characterising the obstacles to improved performance

This diagram has weighted the responses from householders relating to the significance attached to various obstacles (refer to the box below for details) and characterised them into the following four categories:

- Attitudes
- Habits & experience
- Capabilities
- External conditions

The diagram illustrates that the most significant category of obstacles are those that relate to the self-assessed capabilities of householders. The second most significant category of obstacles relate to conditions external to the individual responding, in particular the way the LZC energy technology and the associated controls are arranged within the home.

How were the numbers alongside each obstacle calculated?

In the top left hand corner of the obstacle boxes is a number which represents the significance of each obstacle (for the illustrative purposes of this diagram). This is a 'weighted' total which was calculated in the following way:

Weighted total = (3 x Number of householders who rated the obstacle as extremely significant)
+ (2 x Number of householders who rated the obstacle as very significant)
+ (1 x Number of householders who rated the obstacle as somewhat significant)

Thus the weighting attached to a response is proportional to the significance given to that obstacle. If the obstacle was rated as 'not very' or 'not at all' significant in a response, it was not included in this weighted total.

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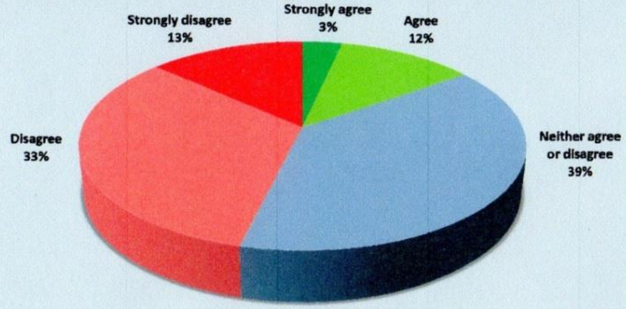
Has the presence of LZC energy technologies led householders to behave differently *away from* their homes due to an increased environmental awareness?

Figure 1. Responses to the statement: 'The presence of your LZC energy technology has led you to behaving differently *away from* your home due to an increased environmental awareness'



Overall response
15% of householders agree or strongly agree that the presence of their LZC energy technology has led them to behave differently *away from* their homes (Figure 1). 46% disagree or strongly disagree that this is the case and the remaining 39% of householders hold a neutral position on this statement.

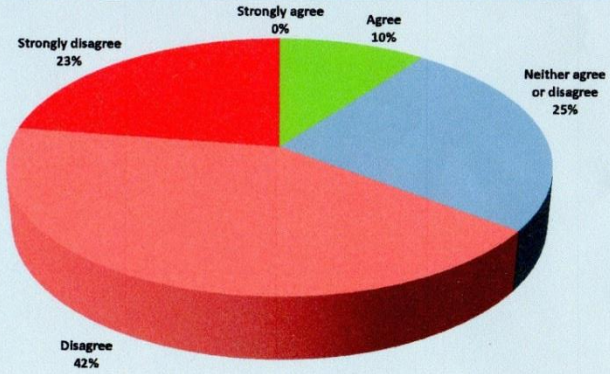
Participants that agreed the technology had caused them to behave differently were asked to provide examples.

Individual responses
- "Drive more efficiently, use less heating & turning lights off – but mainly due to cost savings."
- "Do one car journey rather than several per day."
- "I go by bus where I can."
- "More recycling – checking diesel use in car for efficiency – much economy related."
- "Shopping for appliances, energy supplier."
- "More eco-friendly like reusable bags, cars with better mileage and recycling."
- "More conscious of recycling, low energy options, minimising transport etc."

Individual responses
- "Considering installing several types of LZC technologies in new property on a savings versus capital cost basis."
- "It has increased my awareness of hidden agendas behind 'eco' products and made me increasingly wary of them."
- "When I purchased a new car 18 months ago CO_2 [carbon dioxide] emissions were a key factor in my decision."
- "Selling older cars, buying new build."

Has the presence of LZC energy technologies led householders to get involved with new activities *outside of* the home or with new people?

Figure 2. Responses to the statement: 'The presence of your LZC energy technology has led you to get involved with new activities *outside of* the home or new people'



Overall response
Only 10% of householders agree that the presence of their LZC energy technology has led them to get involved with new activities *outside of* the home or with new people (Figure 2). The majority of householders (65%) disagree or strongly disagree with this statement and the remaining 25% of householders hold a neutral position.

In response to this question, a few householders have given examples of technology-related conversations held with neighbours (who may or may not have become acquaintances without the presence of the LZC energy technology).

Individual responses
- "Spoke to neighbour who has solar panels to see if our system was producing similar results to theirs"
- "Asking neighbours how the system works"
- "Neighbours have common complaints about the systems"
- "Generally more aware and using [knowledge] in professional work"
- "A lot of people have asked about it & looked into schemes to install it" [Air source heat pump is located by front door.]

The role of residents' associations
In a number of the developments studied, residents' associations have been set up.

One of the questions addressed within the interviews is the extent to which these residents' associations act as forums in which the maintenance and operation of the technologies is discussed between residents, and best practices established.

Those interviewed to date, report that their residents' associations have not actively taken on this role where the LZC energy technologies serve individual dwellings.

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Do developments always turn out as expected from planning applications?

Incomplete installation/commissioning of LZC energy technologies
During Phase 1 of the research project, it became evident that there were certain developments where the LZC energy technologies detailed in planning applications had not been installed or, if installed, had not been commissioned. These cases are illustrated by quotes and accounts given by householders and therefore reflect the householders' interpretation of the situation.

Cases 1 & 2 indicate that developers are not always meeting the stipulated planning condition that requires the provision of decentralised and renewable or low-carbon energy sources. Case 3 indicates that for communal energy systems there is a reliance on management companies to operate the energy systems as intended, which may not occur.

1. A resident in one development of 11 dwellings had queried the nature of 'extract' points they had seen around their house, which were evident in each room. A neighbour on the development knew that the houses were designed to enable mechanical ventilation and heat recovery (MVHR), but the systems had not been commissioned. The new properties were, however, marketed as having this technology.

2. "Just to let you know we were meant to have a combined heat and power (CHP) unit installed for all 22 houses, however [the developer] reached their budget so did not install it. We are just standard electricity, standard central heating."

3. "Neither the CHP or biomass systems have been running since the development was completed (nearly a year). We have been and still are running off traditional gas boilers."

This householder lives in a block of 34 apartments and duplex units. Within the planning application, it was stated that the communal CHP system would provide space heating and the communal biomass boiler would provide hot water. The three modular gas boilers installed were designed as a back-up facility.

How should the requirement for LZC energy technologies be applied to assisted living developments?

Contrasting approaches
Two of the new assisted living developments for senior persons in the borough provide examples of contrasting approaches adopted by developers as regards the provision of LZC energy technologies.

The first example is a retirement village of 46 apartments that is served by 4 banks of ground-level photovoltaic (PV) panels and a CHP system. These technologies only serve communal and service areas (such as the kitchen and offices) but the residents are stated as benefiting from lower service charges.

This first example contrasts with a 'housing with care' development consisting of 51 apartments. Here, a solar thermal system provides communal hot water for the kitchens but there are also individual solar thermal systems serving the 11 top floor flats. A resident in one of these apartments stated:

"When moving into this new flat, we had very little information given to us. The manager is of little use."

Another more elderly resident was unable to complete the survey questionnaire, but her daughter/son gave the following comment:

"Householder is [over 90] and has needed much support from a variety of people." "I've filled this [in] on behalf of my elderly mother. Although I am very committed to LZC energy, it of course is of necessity way down the list of issues relating to my mother."

Comment
Expecting elderly occupants of such new developments to effectively operate and maintain unfamiliar LZC energy technologies, without direct assistance, is a questionable practice in terms of achieving optimum usage and of having the potential to cause unnecessary stress.

What role are residents' associations playing?

In a number of the developments studied, residents' associations have been set up. One of the questions addressed within the interviews is the extent to which these residents' associations act as forums in which the maintenance and operation of the technologies is discussed between residents, and best practices established. Those interviewed to date, report that their residents' associations have not actively taken on this role:

1. The first example relates to a development of 24 terraced houses, all with solar thermal technology. The chairperson of the development's residents' association states that the solar thermal systems have never been referred to in the few meetings there have been over the last 4 years, and he does not recall ever having discussed the technology with other residents.

2. The second example relates to a block of 14 apartments, 9 of which have dedicated solar thermal systems. The householder interviewed has recently moved in to the 4-year old apartment and she has not received any guidance relating to the technology from the residents' association. She has, however, received advice from a neighbour on how to use the system.

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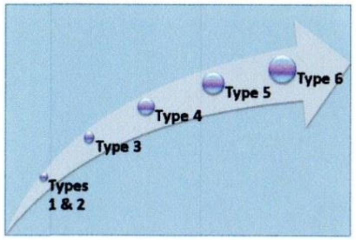
To what degree do householders reject or accept the lower carbon vision/identity placed upon them?

Spectrum of reactions

In reviewing the responses on the questionnaires and in listening to householders talk about their technologies, it is apparent that there is a whole spectrum of reactions to living with unselected low and zero carbon (LZC) energy technologies. This spectrum of reactions encountered has been classified into 6 types to facilitate a discussion of the findings.



Type 1: Intentional rejection & resistance

This group of householders have rejected or are resisting the lower carbon vision/identity placed upon them through the planning system, where they have had an option to do so.

In certain instances, rejection or replacement of installed technologies would entail significant effort and cost (e.g. air source heat pumps) and is therefore less likely to occur. In other instances (e.g. MVHR systems), the rejection of the technology is more easy to achieve.

In the Type 1 cases observed, this intentional rejection or resistance has arisen due to one of the following factors:

- The use of the LZC energy technology has led to or would lead to higher costs than expected; or
- The use of the LZC energy technology has presented a nuisance.

Type 2: Unintentional rejection

In some instances, LZC energy technologies have not been used because householders have been unaware of their presence or have lacked an understanding of what the technologies are for or how they operate. This form of rejection is therefore unintentional and has occurred because householders have an incomplete knowledge relating to the design of their homes.

Type 3: Dissatisfaction & frustration

In certain cases, users are dissatisfied and frustrated with their installed technologies. Common factors cited as the cause of dissatisfaction are that:

- The LZC energy technology, as installed, is faulty; or
- The LZC energy technology has a low level of performance.

Type 4: Disinterest

The fourth type of householder is disinterested in their LZC energy technology. They accept its presence but have no or little engagement with it, and are not intending to change this position.

Type 5: Acceptance with minimal changes to routines

The fifth group of householders accept the use of the LZC energy technologies and may be interested in them, but are not prepared to change their routines/practices in order to improve the benefits gained. They would rather reap a lower level of benefit than have the inconvenience of altering their daily practices that have evolved to suit their needs. They consider that to change their practices would be an unreasonable thing to expect.

Type 6: Acceptance with considered changes to routines

At the most engaged end of the spectrum is a group of householders who are making changes to their daily practices in order to more fully reap the benefits that can be gained from their LZC energy technologies. They are more in tune with the varying performance of their technology and adapt their daily practices accordingly. With solar systems, such changes in practices may be seasonal to reflect the seasonal performance of the technology.

To what degree are the technologies likely to deliver the carbon dioxide (CO_2) reductions envisaged by planners and developers?

Discussion

From the characterisation of types given, the CO_2 reductions achieved are likely to increase from Type 1 users through to Type 6 users. Type 1 users are relying on conventional heating systems only and are therefore achieving none of the CO_2 reductions envisaged through the use of installed LZC energy technologies. The same is likely to be the case for Type 2 users.

Increased CO_2 reduction & increased energy generation achieved

Optimum mode of use & level of maintenance

Type 6	Engagement with technology, changes to routines
Type 5	Engagement with technology, unchanged routines
Type 4	Performance of technology depends on its sensitivity to the low degree of user engagement
Type 3	Assume technology is not functioning as designed
Types 1 & 2	Relying on conventional heating systems only

The dissatisfied and frustrated Type 3 users are by definition not gaining as much from their technologies as they expected (via faults in the system, misuse of the systems or lower levels of performance than might have been expected). It may be that the technologies are not functioning as designed and are therefore not delivering the reductions in CO_2 emissions planned for.

This may also be the case for Type 4 users. However, if Type 4 users have a form of technology installed that does not require much participation by them in order to work effectively, the impact of their disinterest on the reductions in CO_2 emissions achieved may be much lower.

Greater CO_2 reductions might be expected from Type 5 users, with a limiting factor being that householders are not prepared to change their daily routines in order to maximise the benefits gained e.g. they are not prepared to change the time at which they shower.

The achievement of the greatest benefits, and therefore the highest reduction in CO_2 emissions, are achieved by Type 6 users, who are willing to make the necessary changes to their routines to reap greater benefits from their technologies.

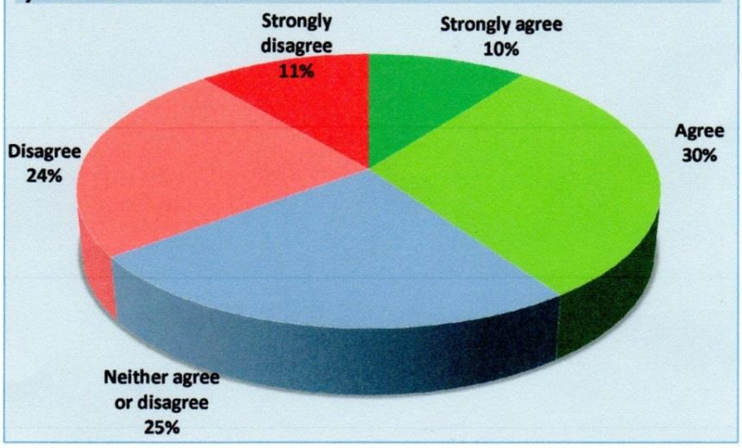
Conclusion

To conclude, the degree to which domestic LZC energy technologies contribute to CO_2 emission reductions and decentralised/low carbon/renewable energy targets is presently highly variable in the geographical area studied.

Has the presence of LZC energy technologies caused householders to do things differently *inside* their homes?

Overall response
In order to obtain an assessment of what proportion of new LZC energy technology users have changed their household practices, participants in the survey were asked whether the presence of the LZC energy technology had caused them to do things differently *inside* their home. 40% of participants agreed or strongly agreed that changes had occurred, whilst 35% did not (Figure 1). The remaining 25% neither agreed nor disagreed that things were being done differently.

Figure 1. Responses to the statement: 'The presence of your LZC energy technology has caused you to do things differently *inside* your home'



Individual responses
Participants that agreed the technology had caused them to do things differently were asked to provide examples. Most of these examples relate directly to **optimising the benefits** gained from solar thermal technology:

- "Trying to put washing on during the day and not in the evening, can't do that with dishwasher as it hasn't got a time delay." [PV & solar thermal user]
- "Use of hot water – I'm more aware of the temperature of the water, whether it's heated up during the day and whether I need to use the electric heater."
- "Reduce amount of time hot water [is] on during summer months."
- "I might consider showering later in the day if it's sunny."
- "Switch off gas boiler from April to October."
- "Changing times we shower to take advantage of the solar heating (afternoon/evening)."

In other examples, from air source heat pump users, the changes in routine were made to **improve the comfort levels** provided by the technology:

- "Heating timing patterns have changed to keep house warm in winter."
- "Heating is set to permanently low setting. Controlled by outdoor thermostat."

Other householders mention changes in routines and behaviours that do not relate directly to the use of their LZC energy technologies but indicate **a raised level of action to reduce energy consumption** around the home, or **a raised level of awareness** on related issues:

- "Be smarter about usage, turning appliances off and radiators down etc."
- "More aware of the potential benefits of changes – capital cost versus potential benefits."
- "Think about energy consumption of appliances and insulation/heat loss in our house."
- " ... more cautious as we measure consumption now."

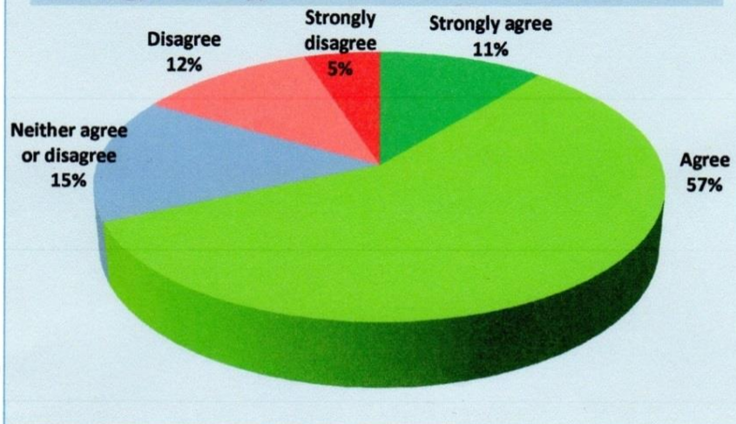
One householder has altered her behaviour to **compensate for recurrent leaks** from her solar thermal system:

- "Keep a watchful eye open for water leaks". "[When going out] I would turn off LZC wherever possible due to [leaks]."

Do householders understand how their household practices may impact on the benefits gained from their LZC energy technology?

Overall response
Participants in the survey were asked to assess whether they understood how their household practices might impact on the benefits gained from their installed LZC energy technology. Figure 1 summarises the results of this self-assessment exercise. The majority of participants (68%) consider that they do understand how their household practices may impact on the benefits gained from their LZC energy technology, whilst only 17% consider that they do not.

Figure 1. Responses to the statement: 'You understand how your household practices may impact on the benefits gained from your LZC energy technology'



Incomplete understanding
In the interviews conducted, there have been certain householders who believe they understand the impact of their practices, but the initial assessment would be that their understanding is incomplete. This disparity may arise because these householders do not fully understand how their systems work and therefore they are not in a position to accurately judge how their practices may affect what can be gained from their LZC energy technologies.

One couple indicated that they understood how their practices impacted on the benefits gained from their solar thermal system. However, they had never referred to any instructions or information relating to the system, nor changed any of their household practices.

They still have their boiler heat the water for two hours in the morning and evening during the summer, as well as in the winter. At no time in four years have they reduced their reliance on the boiler to see whether the solar thermal system could provide sufficient hot water by itself during the summer months.

This disparity is also illustrated by the following example of a householder who indicated that she understood how her household practices impacted on the benefits gained from the LZC energy technology:

This householder lives in an apartment with an installed solar thermal system providing hot water. The hot water system also has a back-up immersion heater. She states that the immersion is left on permanently, winter and summer, as initially set-up by the developer. She has never experimented with the system during the summer to establish whether the solar thermal system can provide all the hot water required. In terms of hot water consumption, she believes that her household practices are likely to have led to an increase in this because she regards the hot water as free:

'I don't worry if I have a long shower or if I decide to have a shower and a bath on the same day ...'

Conclusion
The existence of a proportion of householders who believe they understand the impact of their practices when they do not fully, places a restriction on the degree to which these installations can ever be intentionally optimised.

Appendix 19 – Suggested improvements to feedback for STHW systems

In Section 7.4, Tables 7.1 and 7.2 set out a five-point characterisation of STHW users. The Category V interviewees had certain suggestions on what improvements they would like to see with regards to the content of the feedback made available. It was appreciated that the type of feedback requested was not always necessarily readily deliverable, but it provided an indication of what users would be interested in and what might help them to further engage with, and optimise, their STHW systems. Some interviewees wanted to know whether, at any point in time, their STHW system was contributing to their hot water supply:

> 'Just an 'On' and 'Off' would have been quite useful.' (ID295, STHW)

A number of interviewees wanted feedback on the quantity, or proportion, of heat contributed by the STHW system to their hot water supply:

> 'What would be nice really is to see how much electricity or hot water, whatever, how much does it actually generate, so you could get an idea of what it is actually doing. Other than just the flashing thing on the screen, it didn't really say it's generating 10% of your hot water or 10% of your electricity, or whatever.' (ID295, STHW)

> 'Whether it would be possible to have some way of measuring the heat output from the solar thermal, if you could have an overall energy readout, so you would know: 'Your using this amount of energy, but 20-25% of that is coming from the solar' – that would be interesting.' (ID424, MVHR & STHW)

> 'I guess kind of just percentages – how much is solar thermal and how much is immersion heater.' (ID833, STHW)

Others mentioned that they wanted the monitor to be able to inform them on the length of time, and the actual times, that the STHW system was working during any particular day:

> 'I'd like to see some graph which shows when the immersion heater clicks in and clicks out – so I can have evidence of the impact of real solar heating.' (ID826, STHW)

One Category IV interviewee thought that such information would enable her to tailor the timing of her hot water consumption:

> '… if it could give me a start and cut-off time, then I know if I am using water after that time, then it's only topping up with cold… it's not getting re-heated *[by the STHW system]…* Yes, it would be more useful that way round if it could tell me what it was doing, so I could then work out what I was going to do with it .' (ID1030, STHW)

Others would like to know how much they are benefitting financially:

> 'I would like to know how much it's actually saved me…' (ID958, PV & STHW)

This last householder also had a PV system, which was fitted with a meter that logged the cumulative quantity of electricity the system had generated; because he knew the financial benefits gained through the Feed-in Tariff (FIT), he could assign a demonstrable value to the PV system. This he could not readily do for the STHW system, which frustrated him.

In summary, there was a common view amongst those in this category that they would benefit from more informative feedback with which they could engage; such as what proportion of their hot water needs were being met by the STHW system; at what times the system was working on any particular day; and how much they were saving in monetary terms.

Appendix 20 – Article in *Area* journal

Royal Geographical Society with IBG
AREA
Area (2013) 45.4, 469–476 doi: 10.1111/area.12057

What enhances the relevance of this low carbon policy research? A strong blend of pertinence, commitment, application and trustworthiness

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Revised manuscript received 9 July 2013

This paper explores the factors that enhanced the relevance achieved by a specific research project concerned with the implementation of a local carbon policy in the UK. This policy required the installation of low and zero carbon (LZC) energy technologies within new homes throughout a particular borough. Sensitive to the contingent nature of relevance, the aim of the paper is not to propose universal determinants for achieving relevance in research but to crystallise out the multitude of factors that have enabled this specific piece of research in the field of human geography to reach and function effectively at the research/policy interface. The initial framework employed explores these factors under three sub-headings derived from the extant research literature: pertinence, commitment and application. The issue of trustworthiness is then introduced as an additional sub-heading worthy of consideration in relation to the contributing processes at work in building this research's relevance.

Key words: *relevance, research/policy interface, qualitative research, new homes, low and zero carbon energy technologies, Woking*

Introduction

The relevance of geographical research has been debated from various perspectives, such as its relevance to policy-making or lack thereof (Peck 1999 2000; Banks and MacKian 2000; Pollard *et al.* 2000; Martin 2001; Dorling and Shaw 2002; James *et al.* 2004; Burgess 2005; Owens 2005; Phelps and Tewdwr-Jones 2008), its specific relevance to environmental policy-making (Castree 2005; Eden 2005) and the distance of certain sectors of the discipline from ' "relevance" in general' (Peck 1999, 132).

The meaning of relevance within human geography has also received attention (Dear 1999; Pacione 1999; Staeheli and Mitchell, 2005). Staeheli and Mitchell argue that what determines research's relevance

> cannot be separated from the questions of *why* research should be relevant, *how* research becomes relevant, the *goals* of research, and *for whom* it is intended to be relevant. (2005, 357)

These authors build upon work by Dear (1999) in furthering the discussion on how pertinence, commitment and application[1] contribute to relevance. In this paper, I discuss these aspects of relevance not in broad terms but in the context of a specific research project, filling out this framework by generating a more detailed evaluation of contributing factors, shown diagrammatically in Figures 1 and 2. The issue of trustworthiness is then introduced as an additional aspect of relevance worthy of consideration.

Before proceeding with the discussion on relevance, an outline of the specific research project on which it is based is given.

In 2005, Woking Borough Council (WBC) adopted a progressive low carbon policy requiring all new residential developments to meet 10 per cent of their predicted energy demands through the use of low and zero carbon (LZC) energy technologies (such as solar thermal systems and air source heat pumps). In 2012, all current occupants of homes built to this policy, within the borough, were invited to participate in research designed to evaluate their experiences with these unfamiliar, unselected technologies. Further details of the research will progressively emerge within the paper.

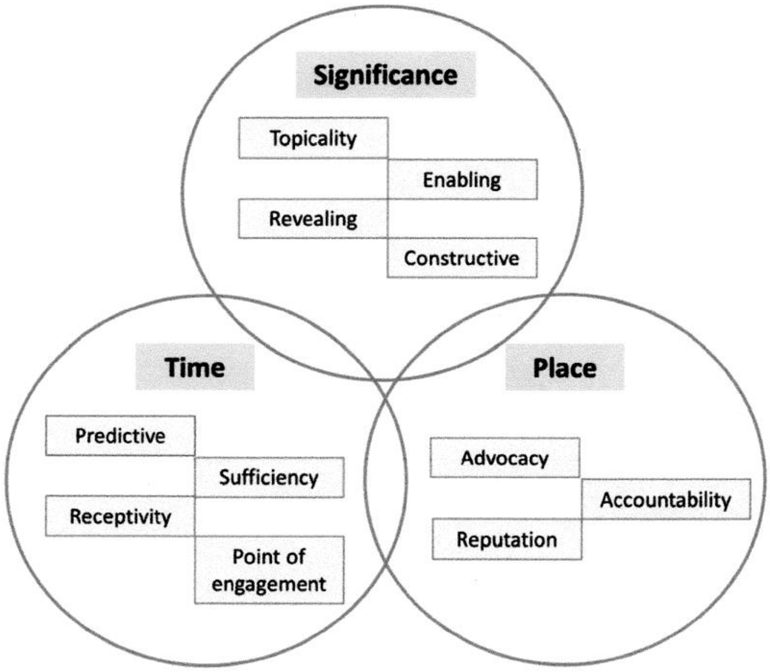

Figure 1 Factors contributing to the pertinence of the research

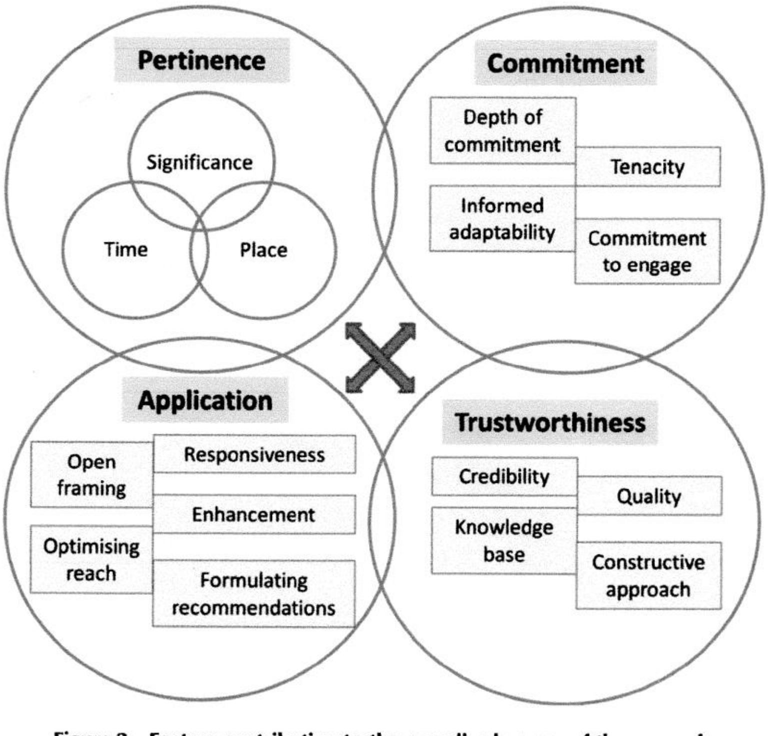

Figure 2 Factors contributing to the overall relevance of the research

A brief outline of the extant relevance framework: pertinence, commitment and application

Pertinence

Pertinence is something which 'has significance (however defined) for a particular time and place' (Dear 1999, 144). Although interdependent, significance, time and place are separated out in the ensuing analysis to help elucidate the factors that contributed to the pertinence of the research.

Commitment

> Agenda setting, contributing to concern issues, and contributing directly to the solution of some specific problem all require the making of *commitments* . . . (Staeheli and Mitchell 2005, 363)

This commitment might manifest itself in the research questions posed, the research methodology employed or in the way the researcher enlists others' support to address research findings. As Martin states, there is 'no such thing as "neutral" research', and he argues for researchers to be 'more explicit about, and more committed to, the political positions' that influence their work (2001, 202).

Application

To achieve relevance, some consider that research has 'to result in application or action' (Staeheli and Mitchell 2005, 364). Accordingly, findings need to be expressed in meaningful and usable terms that will lead others to act. The generation of usable knowledge is facilitated by a clear conception of who eventual users might be but, as argued by Owens (2005, 288), the identification of potential users 'in advance of the research findings that they will use' is not straightforward. Where envisaged users belong to a single category (e.g. house-builders), research questions can be framed to maximise the usability of the findings to them. Where a myriad of user groups might be interested (from local authorities to technology installers), research questions are better framed to yield usable knowledge for multiple user types, employing 'open' as opposed to 'targeted' framing.

Application of the extant relevance framework: pertinence, commitment and application

Firstly, does this research have pertinence?

The pertinence of the research is explored by addressing issues relating to its significance, and the time and place at which it was undertaken.

Significance. In deriving the salient 'significance' factors, the research features discussed centre on its connection to a major concern of our time (Staeheli and Mitchell 2005) and to everyday experiences of new home occupants.

The research contributes to the work of mitigating climate change by studying how the use of LZC energy technologies, within new homes, can be improved to help deliver envisaged carbon dioxide reductions. Climate change is a key issue as evidenced by the international agreements, legislation, local policies, education and media coverage associated with it.

Where research is associated with a major issue, the perception of its significance is enhanced by its topicality and by the contribution it can make to addressing the issue. This research took place in the borough of Woking (Surrey, UK) and WBC affirms that climate change is one of the 'most important issues' it has to 'tackle' and, as a Beacon Authority,[2] they are 'leading the way' (WBC 2008, 3). The research topic is therefore closely aligned with one of WBC's self-declared priorities.

The research is grounded in the everyday experiences of householders who live with unselected, unfamiliar LZC energy technologies, and has highlighted issues that need addressing (e.g. misunderstandings, lack of information and limited opportunities to discuss the technologies). This focus on residents is aligned with an area for action identified in WBC's Climate Change Strategy: that of 'Community and Residents' (WBC 2008, 38). The research contributes to efforts to engage residents on the wider topic of climate change but more specifically on optimising LZC energy technologies. This potentially adds significance to the research from WBC's perspective because it is aligned with their policy agenda and may assist with undertakings made.

Furthermore, the research has particular significance to WBC because it reveals deficiencies associated with their 10 per cent LZC energy policy (e.g. faulty installations, disengaged householders). By examining the outcomes from this policy, the research has constructively brought '*new* issues to the table' (Staeheli and Mitchell 2005, 362). The research findings and constructive framing of recommendations has the potential to drive improvements in 'policy practice' (James *et al.* 2004, 1901) as they impinge on processes of policy implementation, enforcement and feedback.

In summary, the four 'significance' factors proposed as contributing to the pertinence of the research are 'topicality' (selecting a research topic that relates to a major issue), 'enabling' (enabling the achievement of undertakings made by others), 'revealing' (revealing system deficiencies) and 'constructive' (framing research findings and recommendations to facilitate productive developments in systems) (Figure 1).

Time. In deriving the salient 'time' factors, the features discussed centre on regulatory changes, the availability of research participants, the policy development cycle and early engagement with others.

This research took place during a transformational period for the house-building sector. Step-wise regulatory changes, specifying energy performance standards for new dwellings, have been mapped out for the period 2010 to 2016 (DCLG 2012). By 2016, notional 'zero-carbon' homes will be the required norm and LZC energy technologies will be a feature of new homes nationwide. Certain local authorities have adopted innovative ' "bottom-up" planning initiatives' (Martin 2001, 204) requiring the installation of such technologies, well ahead of these changes to the national regulatory landscape. WBC, for instance, adopted their 10 per cent LZC energy policy in 2005 and examining such 'test-beds' can highlight issues other regions will encounter as tougher standards are introduced. This research represents what Cummins refers to as the 'evaluation of naturally occurring experiments in urban contexts' (2003, 221) and such research has the potential to impact on policy and processes beyond its locality (James *et al.* 2004, 1903).

In assessing whether the borough of Woking presented a suitable research area, the time the 10 per cent LZC energy policy had been in place was key. With the fieldwork scheduled for 2012, this provided an adequate period of time after policy adoption (i.e. 7 years) for implementation issues to have emerged and for the number of new home occupants to be sufficient to form a basis for research.

The timing of the research was also opportune in that WBC was at a receptive stage in their policy development cycle, at which they could more readily act on recommendations arising. This was unknown initially but became apparent during discussions of the preliminary research findings. By then, the Independent Planning Inspector had accepted WBC's proposed Core Strategy (Seaman 2012) (the guiding document for planning for the next 15 years) and policy makers were formulating the Supplementary Planning Document (SPD). This provides developers with further details on issues like sustainable building design and it was considered that certain research recommendations could potentially be addressed by inserting additional planning guidance into the emerging SPD (e.g. guidance on LZC energy technologies in assisted living developments, specifying the use of certified LZC products and installers).

Thus, the timing of the research was aligned with the policy development cycle, enabling particular recommendations to be implemented earlier than would otherwise be possible.

The point at which potential users of research findings are engaged with may impact on the research's relevance. Where engagement commences while findings are 'fresh', and possibly still emergent, it may be easier to draw off aspects of the research that are of particular interest. In contrast, inundating potential users with findings that include much of irrelevance (from their perspective) may diminish the perceived relevance of the research to them. The value of 'brevity' in research outputs intended for 'bureaucrats' is something recognised by Mountz and Walton-Roberts (2006, 265). Once research findings are published, it may be harder for others to extract the most from them as details become omitted and the agency of the research reduced. Also access to the researcher, in order to explore findings further, may become problematic.

In conclusion, the four 'time' factors proposed as contributing to the pertinence of the research are 'predictive' (undertaking research at a time when findings can predict effects of forthcoming widespread changes), 'sufficiency' (undertaking research once sufficient data on issues has emerged), 'receptivity' (undertaking research at a receptive point in the policy development cycle) and 'point of engagement' (engaging early with potential users of the research) (Figure 1).

Place. In deriving the 'place' factors that have contributed to the pertinence of the research, the features discussed centre on its borough-wide extent, the nature of the user of the research findings and the influence of key individuals and groups.

The research area was confined to a single borough and this approach was adopted partly because it was anticipated that it would maximise the authority's accountability for addressing any shortfalls highlighted.

Selecting the jurisdiction of WBC for the research was considered appropriate because they have received the Beacon Award[2] for their sustainable energy approach on three successive occasions between 2005 and 2008 (WBC 2010). As such, WBC has a reputation to maintain and this may have contributed to the pertinence of the research to them, i.e. the weighting attributed to the findings may have been, in part, a function of the authority's reputation.

The last 'place' factor concerns a chain of individuals and groups who helped secure the research's relevance. The first is the planning policy officer who was the only point of contact at WBC prior to an exhibition of preliminary research findings in May 2012. From initial meetings, it was apparent that the research was recognised as providing a useful policy evaluation (Johnston and Plummer 2005, 1523). This officer was instrumental in marshalling key WBC personnel to the exhibition and served as the initial 'champion' for the research.

At the exhibition, the 'baton' of support was grasped by the chairperson of WBC's Climate Change Working Group, who requested I attend the Group's next meeting to present the findings and discuss recommendations for action. Subsequently, WBC adopted the recommendations and the 'baton' of support transferred to the wider membership of the Group, who are now managing their implementation. The continuous chain of advocacy from early engagement to implementation of recommendations is considered key to securing the research's relevance.

In conclusion, the three 'place' factors proposed as contributing to the pertinence of the research are 'accountability' (selecting a research area for which there is an accountable organisation), 'reputation' (selecting a research area where the accountable organisation has a reputation to uphold) and 'advocacy' (the presence of a continuous chain of advocacy to help secure the research's relevance) (Figure 1).

Secondly, does this research show commitment?

In deriving the 'commitment' factors that have contributed to the research's relevance, the features discussed centre on the role of moral frameworks in setting the research agenda and the role of motivation in achieving research objectives. In addition to the researcher's commitment, that of the potential users of research findings is also considered.

Commitment of the researcher. When a researcher is driven by their political commitment, their research will have *personal* relevance. In such instances, a researcher might experience a greater impetus to ensure their research can be (and is) made of relevance to others.

Reflecting on the commitment exhibited by myself, it can be viewed as an environmental commitment operating at multiple levels. On a general level reflecting my 'normative vision' (Staeheli and Mitchell 2005, 363), I am driven to combat the adverse environmental impacts from human activities, and at the issue level, I wish to participate in efforts to mitigate against climate change. At the specific level of the research project, my motivation (Staeheli and Mitchell 2005) is to contribute to understandings of how LZC energy technologies are being used, and to consider how the current situation can be improved on to maximise reductions in carbon dioxide emissions. Thus, there may be multiple layers of commitment that underlie that manifested at the project level.

A researcher's commitment can influence not just the research approach but also the tenacity with which research is pursued and findings disseminated. When obstacles to progress emerge, having the commitment to deliver on the original intent of the research will promote the formulation of alternative trajectories that maintain the research's relevance. For this research, the final phase of fieldwork was to involve the creation of a householder support network, though this proved unsuccessful due to insufficient participation. Consequently, in continued pursuit of the research aims, efforts were redirected to engaging more fully with WBC. Thus, the researcher's commitment can have a pivotal influence at multiple stages of the research process.

Commitment of others. The commitment of collaborators may also influence the research's relevance. Here, there was early engagement with WBC, informing them of intentions and progress, but their involvement in the design and execution of the research was minor and was therefore not considered to be a form of collaboration that influenced the fundamental nature of the research. However, it is proposed that this early engagement heightened WBC's perception of the relevance of the research *to* them and helped secure their commitment to engage with the findings.

In conclusion, the four 'commitment' factors proposed as contributing to the research's relevance are 'depth of commitment' (multiple layers of commitment underlying that manifested at the project level), 'tenacity' (steadfast pursuit of research objectives and dissemination of findings), 'informed adaptability' (ability to adapt the research trajectory in response to changing circumstances) and 'commitment to engage' (early engagement with others to heighten their perception of the research's relevance to them/commitment by others to engage with the research) (Figure 2).

Thirdly, does this research have application?

In deriving the 'application' factors that have contributed to the research's relevance, the features discussed centre on the framing of research questions, findings and recommendations, and the onward application of findings.

For this research, it was envisaged that usable knowledge could, dependent on interest, be generated with/for a variety of groups, e.g. residents, developers and local authorities. However, the interest that would be realised from these groups was unknown and work was required to 'bring forth' these potential 'publics' (Ward 2007, 702). This inherent unpredictability of the research process is commented on by Mountz and Walton-Roberts:

> researchers cannot know as they conceptualize a project all of its intended findings or how they might be taken up by diverse groups working toward a variety of political goals over time. (2006, 264)

Residents were invited to one exhibition of preliminary research findings and other parties were invited to a second exhibition. Here, it was representatives from WBC who expressed willingness to act on the findings and this led to a change of focus in the last phase of fieldwork. To this extent, the research trajectory was responsive to the party that, firstly, recognised there was a 'problem calling for a solution' (Johnston and Plummer 2005) and, secondly, was willing to take on the responsibility of working on that solution.

This process of responding to an expression of interest resonates with an extract from Massey who, in talking about the outputs from academic work (such as publications), laments that

> It is all too easy for the emphasis to be on that rather than on the notion of launching something into a stream, a proliferation of connections, to see how it will fare, how it will affect and be affected. (2000, 133)

Exhibiting the research findings with an open invitation to many felt somewhat like 'launching' the findings 'into a stream' (Massey 2000, 133) in order to see who would 'bite'; who would be keen to pursue matters further. Rather than letting go of the findings at this point, I accompanied them 'downstream' in association with an interested other to help the findings effect informed change.

It was always the intention to engage with WBC towards the end of the research in order to transfer findings to them. However, working with WBC while still in 'fieldwork' mode changed the nature and extent of this engagement to one of reflecting jointly on the findings and of thinking through how the recommendations could be operationalised. Such discussions have involved staff assigned to different functions (e.g. building control, planning policy, development control and the energy advisory centre) and relevant findings have been extracted and framed from the perspective of these distinct but linked functions. Thereby, efforts have been made to 'translate such work into a policy context' (Martin 2001, 198) and these efforts are aligned with the view that 'it is vital to feed research findings actively into the deliberations of those bodies empowered to formulate policies' (Castree 2005, 272).

In extracting actionable findings, judgements have been made on what is in WBC's realm to address, i.e. what are 'achievable reforms' (Martin 2001, 203) from the local authority perspective. I have also prioritised what I considered to be the five key recommendations (as requested by WBC), and these were framed to address the majority of the relevant findings. This stage in the research process illustrates how a researcher can play a key role in optimising their work's application, not only by framing research findings but also by framing associated recommendations for action. As Johnston and Plummer suggest, 'Policy makers will not tackle a problem if there is no accepted solution' (2005, 1523). To address residents' queries and misunderstandings relating to LZC technologies, for example, a series of Q&A style articles have been recommended for the energy advisory centre's website and the borough's community magazine.

In exploring the application of research, ascertaining how far the relevance of the research reaches may be appropriate. For example, if this research had been limited to householders with one uncommon form of technology installed (e.g. ground source heat pumps), the findings may have remained associated solely with this installation type. In contrast, if the research's reach is considered extensive (e.g. it applies to all homes built with installed LZC energy technologies), then it may leverage greater impetus to act upon it as the consequences of doing so will affect a broader public. Thus, the incentive to act upon the research may be determined in part by its reach (in terms of the present and future number of ultimate 'beneficiaries' (Staeheli and Mitchell 2005, 357) of improvements).

In conclusion, the five 'application' factors proposed as contributing to the relevance of the research are 'open framing' (framing research questions to yield usable knowledge for multiple user types), 'optimising reach' (selecting research questions and research participants so as to optimise the research's reach), 'responsiveness' (aligning the research trajectory in its last stage with the requirements of the party expressing the greatest interest in acting upon the research), 'enhancement' (presenting research findings in a manner that enhances the research's relevance for interested users) and 'formulating recommendations' (formulating prioritised recommendations for action for targeted groups) (Figure 2).

Extending the relevance framework to incorporate trustworthiness

What contribution does trustworthiness have to the relevance of research?

One aspect of relevance that appears insufficiently covered by considerations of pertinence, commitment and application is that of trustworthiness. This section considers the significance of trustworthiness in relation to this research's relevance.

Firstly, the degree of trust in, or credibility of, a researcher is likely to affect whether others associate with the research and potentially lend their name to it, thereby endorsing its relevance. Credibility was partly attained through my affiliation to a university and through distributed materials and communication, but it was considered that an endorsement by WBC could promote a higher householder participation rate and thus this was requested. WBC agreed that I could state: 'This survey has been undertaken using information supplied by Woking Borough Council'. This semi-endorsement may have increased the research's trustworthiness as perceived by would-be participants.

Secondly, the degree to which a researcher is trusted may affect the value or relevance (or 'degree of confidence' (Mountz and Walton-Roberts 2006, 268)) attached to the findings. The fact that the research process and I as researcher were sufficiently trusted helps account for the rapidity and extent to which research findings were disseminated through WBC. It also helps account for why I was asked to put forward recommendations, which were subsequently adopted.

My experience of working in the sustainable building sector and with planning departments would have contributed to my trustworthiness as perceived by WBC. This experience afforded a good working knowledge of the sector, which underpinned discussions on the research and also gave me confidence in formulating relevant recommendations for action.

There was also an appreciation of how policy implementation can generate unintended effects that take time to emerge and be recognised as requiring corrective actions.

> If geographers are to engage more with the policymaking process, they need to begin with an understanding and an acceptance that failure and unanticipated consequences are endemic in policy processes. (Phelps and Tewdwr-Jones 2008, 577)

Such an appreciation helps researchers avoid a purely critical approach to policy processes and instead pursue a constructive one, seeking to understand not only why the unintended effects have arisen but also what changes could help prevent their continued occurrence. A constructive approach opens up possibilities for a more trusting dialogue with policymakers as it signifies the researcher's intention to assist. This concurs with the opinion that it is 'easier to shift policy-makers' views if criticism is constructive, that is accompanied with positive suggestions for improving or changing policy' (Martin 2001, 200).

In conclusion, the four 'trustworthiness' factors proposed as contributing to the research's relevance are 'credibility' (attaining sufficient credibility through an affiliation to an academic establishment and via endorsement from relevant groups), 'quality' (generating material and communications that possess clarity and pertinence), 'knowledge base' (possessing a good working knowledge of the researched sector) and 'a constructive approach' (adopting an approach that assists rather than purely criticises) (Figure 2).

Summary

This paper extends the extant relevance framework to incorporate trustworthiness. The range of factors proposed as contributing to the research's relevance are summarised in Figures 1 and 2 under the sub-headings of pertinence, commitment, application and trustworthiness. This multitude of contributing factors illustrates the 'multi-faceted nature of relevance' (Staeheli and Mitchell, 2005, 368). The relative contribution of each to the relevance of any particular research study would be expected to vary (Staeheli and Mitchell 2005) as there is a 'situational contingency' to what determines relevance (Castree 2005, 271), and that includes the 'normative stance' of who makes this assessment (Staeheli and Mitchell 2005, 369).

The unravelling of relevance into its contributory determinants, as presented in this paper, illustrates how relevance is influenced by the viewpoints, circumstances and actions associated with those connected with the research, e.g. researcher, research participants and users of the research. This interpretation is broader than that offered by Staeheli and Mitchell (2005, 368) who view relevance more as 'a function of users'. Just as this narrower viewpoint does not apply well to this research, the interpretation of relevance as provided here may hold for policy-oriented research but not be wholly applicable to approaches such as participatory action research, where the research participants play a much greater role in determining relevance (see Pain *et al.* 2011). In this way, 'what constitutes relevance' (Staeheli and Mitchell 2005, 368) can be seen also to be a function of the research approach.

As reflected on by Owens, 'our understanding of processes operating at the knowledge/policy interface remains incomplete' and, as such, she puts forward 'the need for more research into and at the "boundary"' (2005, 290). The crystallising out of the various factors in this research that have enabled it to reach and function effectively at the research/policy interface provides an insight into the contributory processes at work in this particular 'boundary space' (Owens 2005, 290).

Acknowledgements

This paper is based on research supported by the Royal Geographical Society (with the Institute of British Geographers) with a Postgraduate Research Award. I would like to thank the anonymous reviewers for their valuable comments on an earlier draft of this paper.

Notes

1 Staeheli and Mitchell (2005) also incorporate two further aspects into their discussion of relevance: centrality and teaching. It is not considered that this research can be judged against these aspects at this stage in the research process (i.e. prior to publication).

2 The UK government's Beacon Scheme recognises excellence in local government and seeks to distribute examples of best practice among local authorities.

References

Banks M and MacKian S 2000 Jump in! The water's warm: a comment on Peck's 'grey geography' *Transactions of the Institute of British Geographers, New Series* 25 249–54

Burgess J 2005 Commentary: Follow the argument where it leads: some personal reflections on 'policy-relevant' research *Transaction of the Institute of British Geographers, New Series* 30 273–81

Castree N 2005 Forum: Geography and environmental policy. Introduction *Transactions of the Institute of British Geographers, New Series* 30 271–2

Cummins S 2003 From observation to experimentation: one prescription for a geography of public policy *Area* 35 220–2

DCLG 2012 *2012 consultation on changes to the Building Regulations in England: Section two – Part L (Conservation of fuel and power)* Department of Communities and Local Government, London

Dear M 1999 The relevance of postmodernism *Scottish Geographical Magazine* 115 143–50

Dorling D and Shaw M 2002 Geographies of the agenda: public policy, the discipline and its (re)'turns' *Progress in Human Geography* 26 629–46

Eden S 2005 Green, gold and grey geography: legitimating academic and policy expertise *Transactions of the Institute of British Geographers, New Series* 30 282–6

James A, Gray M, Martin R and Plummer P 2004 Commentary: (Expanding) the role of geography in public policy *Environment and Planning A* 36 1901–5

Johnston R and Plummer P 2005 What is policy-oriented research? *Environment and Planning A* 37 1521–6

Martin R 2001 Geography and public policy: the case of the missing agenda *Progress in Human Geography* 25 189–210

Massey D 2000 Editorial: Practising political relevance *Transactions of the Institute of British Geographers* 25 131–3

Mountz A and Walton-Roberts M 2006 Gender, geography and policy:the conundrums of engagement *GeoJournal* 65 263–73

Owens S 2005 Making a difference? Some perspectives on environmental research and policy *Transactions of the Institute of British Geographers, New Series* 30 287–92

Pacione M 1999 Guest editorial *Scottish Geographical Journal* 115 v–xiv

Pain R, Kesby M and Askins K 2011 Geographies of impact: power, participation and potential *Area* 43 183–8

Peck J 1999 Grey geography? *Transactions of the Institute of British Geographers, New Series* 24 131–5

Peck J 2000 Jumping in, joining up and getting on *Transactions of the Institute of British Geographers, New Series* 25 255–8

Phelps N and Tewdwr-Jones M 2008 If geography is anything, maybe it's planning's alter ego? Reflections on policy relevance in two disciplines concerned with place and space *Transactions of the Institute of British Geographers* 33 566–84

Pollard J, Henry N, Bryson J and Daniels P 2000 Shades of grey? Geographers and policy *Transactions of the Institute of British Geographers* 25 243–8

Seaman A 2012 *Report on the examination into Woking local development documents Core Strategy July 2011 Local Plan* The Planning Inspectorate

Staeheli L and Mitchell D 2005 The complex politics of relevance in geography *Annals of the Association of American Geographers* 95 357–72

Ward K 2007 Geography and public policy: activist, participatory, and public geographies *Progress in Human Geography* 31 695–705

WBC 2008 *Climate change strategy 2008–2013* Woking Borough Council, Woking

WBC 2010 *Beacon authority, tackling climate change* (http://www.woking.gov.uk/environment/climate/Greeninitiatives/beacon) Accessed 17 October 2012

Appendix 21 – Dwellings where LZC technology was absent

As mentioned in Section 5.6, it became apparent that not all the targeted households had LZC technologies installed. Stated reasons or derived explanations for this varied as exemplified by the following cases:

Case 1 – All 51 households within an extra care home[152] for the elderly were included within the questionnaire survey. However, only the 12 top floor flats were found to have dedicated STHW systems installed, with a communal STHW system serving the communal kitchen.

Case 2 – All 46 households within a retirement village were included within the questionnaire survey. However, through feedback received, it was apparent that the technologies installed (four rows of ground-based PV panels and a CHP system) only served communal areas. Thus, none of the 46 households fell within the target population of the survey[153].

Case 3 – In a development of 9 detached properties, feedback established that only two properties had LZC technology installed (in the form of an ASHP). There were a few cases such as this where the developer had strived to meet the low carbon energy target for a development by focusing on providing a high percentage of low carbon energy for a sub-set of the units.

Case 4 – In a development of 11 semi-detached properties, feedback established that the properties were designed and marketed as each having a MVHR system. There are evident extract points in various rooms, for example. It is not known whether all the necessary components of the MVHR system are installed but it is known that the systems were never commissioned. Thus, the occupants of these homes could not meaningfully complete the questionnaire.

Case 5 – In a development of 22 terraced houses, feedback indicated that there should have been a CHP system serving all the homes but the developer (a housing association) ran out of funds and did not install it. The intention to install a CHP unit was confirmed within the planning application.

There were also a couple of recently built developments containing unoccupied units.

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[152] Extra care developments can take a variety of forms (see Housing Learning and Improvement Network, 2008). In this particular case, the residents owned their self-contained flats but had access to a communal lounge area and restaurant.

[153] Where it was found that dwellings were served by LZC technologies for communal purposes only (such as lighting and heating of communal areas), they were excluded from the survey as the research questions were generally not applicable to them.

Cases 4 and 5 highlight that there are issues of policy compliance and enforcement to be resolved. This subject, however, was outside the scope of the current research.

Reference

Housing Learning and Improvement Network. (2008). *Extra care housing - what is it?* Retrieved March 10, 2014, from http://www.housinglin.org.uk/_library/Resources/Housing/Housing_advice/Extra_Care_Housing_-_What_is_it.pdf